LIVES

OF THE

ENGINEERS.

HARBOURS—LIGHTHOUSES—BRIDGES.

SMEATON AND RENNIE.

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BY SAMUEL SMILES,

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> "Bid Harbours open, Public Ways extend;
> Bid Temples worthier of God, ascend,
> Bid the broad Arch the dang'rous flood contain,
> The Mole projected break the roaring main,
> Back to his bounds their subject sea command,
> And roll obedient rivers through the land!
> These honours Peace to happy Britain brings,
> These are imperial works, and worthy kings."
>
> POPE.

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LIVES

OF

SMEATON AND RENNIE.

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INTRODUCTORY CHAPTERS.

CHAPTER I.

SHIPPING AND HARBOURS.

THE Commercial greatness of England is of almost as modern a character as its Engineering. England had very little foreign commerce before the middle of last century. It did not begin to assume any special importance until the steam-engine had been invented by James Watt.

The Maritime greatness of England is also of comparatively recent growth. Although the sea is now regarded as the national business of Englishmen, scarce two centuries have elapsed since England was unable to defend her coasts against foreign pirates.

At a time when Spain, Holland, France, Genoa, and Venice were great maritime powers, England was almost without a fleet, its trade with other countries being conducted principally in foreign ships.

Until the middle of the sixteenth century, the Foreign Company of Merchant Adventurers monopolized almost the entire foreign trade of London. Their headquarters were in the Hanse Towns of Germany, and they carried on their trade with England under the protection of a special code of mercantile law. They occupied large premises in Upper Thames Street, London—where they had their Guildhall, dwellings, and warehouses, surrounded by a strong wall,—together with a wharf on the Thames.*

The privileges of the foreign merchants were withdrawn in 1552, because they were considered prejudicial to the growth of native commerce; but what the state of the English merchant navy was about that time, may be inferred from the fact stated by the Secretary to the English Company of Merchant Adventurers, that in 1540 there were not more than *four* merchant ships of above 200 tons each, belonging to the river Thames! †

Bristol, then next in importance to London, possessed several large foreign-built ships; but the principal craft belonging to that port was only of from 50 to 100 tons burden. In Queen Elizabeth's time Liverpool was a poor decayed town, and petitioned, in 1571, to be relieved from a royal subsidy; the entire shipping of the place amounting to only 223 tons,—the largest vessel being only of 40 tons burden.

It is astonishing, however, to find what bold and daring things were done by the Englishmen who navigated these ships. The sea-going blood was in them, and wherever the ship would float, the seamen were ready to go. Sir Humphry Gilbert crossed the Atlantic, and sailed along the coast of America in the 'Squirrel,' of only 10 tons! Sir Francis Drake's fleet, which left the English shores for the circumnavigation of the globe, consisted of five vessels, the largest of which was not of 100 tons burden.*

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* The Company was denominated "The Steelyard Company of Foreign Merchants," partly because they imported nearly all the iron and steel used in England. They also imported all the spice, fine cloth, silks, and other foreign commodities; the only article which they exported being English wool, for the purpose of being made into cloth in the Low Countries and Germany. The Cannon Street Station now occupies the site of the Steelyard Company's premises. The Hanse Towns Corporation continued to hold the property until within the last few years.

† Macpherson's 'Annals of Commerce,' ii. 85. [Ed. 1805.]

In those early days, the Companies of English Merchants seem to have laid the foundations of our colonial greatness. They were most enterprising in the discoveries which they promoted. Thus the Merchant Adventurers of the Muscovy Company endeavoured to find a way, by the North-East Sea, to Japan and China. The brave navigator Hudson made his first voyage into the Frozen Seas in an ill-found little craft of about 80 tons, accompanied by a crew of twelve men and a boy. Arthur Pet and Charles Jackman penetrated to the Kara Sea through the Tugor Strait, in two little ships—one of 40 tons, with nine men and a boy, and the other in a boat of 20 tons, with five men and a boy.

Martin Frobisher was another of these early maritime heroes. Under the patronage of some private persons, and of the Company of Foreign Merchants, he set out, in the reign of Elizabeth, to discover the North-West Passage to China. His fleet consisted of two small craft of 24 tons each—scarcely the size of Thames yachts, and both poorly found—accompanied by a pinnace of 10 tons! And some years later—for the discovery of the North-West Passage seems to have continued the dream of mariners down to our own time—Robert Fotherby, in 1615, assisted by the East India Company and the Company of Foreign Merchants, set out in the 'Richard,' accompanied by Robert Baffin as his pilot, to discover the same passage to glory and wealth.

The royal navy was on a par with the mercantile; and at the time when the Spanish Armada bore down upon the English coast, it consisted of only twenty-three ships, eight of which were under 120 tons. There were only nine of 500 tons and upwards, the ship of the greatest burden being of 1000 tons, carrying only forty guns. The principal part of the fleet which held at bay the Armada until the storms had scattered it, were coasting-vessels of small burden, belonging to Lyme, Weymouth, and other ports along the southern coast. Of the whole seventy-five vessels which constituted the squadron under the Lord Admiral and Sir Francis Drake, not fewer than sixty were from 400 tons down to as low as 20 tons. About the same period, the small but flourishing republic of Venice possessed a fleet of more than three thousand vessels of various kinds, carrying upwards of thirty-six thousand seamen.

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* One of Sir Francis Drake's ships, the 'Golden Hind,' was used, until recently, as a Thames barge. Another interesting little vessel, the 'Investigator,' of about 150 tons, used to lie moored off Somerset House, where it was used as one of the floating stations of the Thames River Police. The 'Investigator' was the vessel in which Capt. Ross made his first voyage to the Polar Seas in search for the North-West Passage.

The English navy, however, made gradual progress. Its growth was quickened by the commercial spirit of the people. In 1613 there were ten vessels of 200 tons belonging to the port of London. The suppression of the foreign monopoly of the carrying trade had the effect of giving a considerable impetus to the English shipping business; and by the year 1640 we find the number of ships and sailors more than trebled. We had not yet, however, obtained our proper ascendency. Van Tromp was still able to sail up the Channel with a broom at his mast-head, showing that he had swept his English foes from off the seas. The Dutch, in fact, then displayed those qualities of commercial enterprise, adventurous discovery, and fighting power at sea, on which the English people now pride themselves.

The Dutch not only beat our fleets, but fished our coasts, just as the English, Scotch, and French fishermen now fish the coasts of Ireland; and the Dutch then upbraided us for our idleness and stupidity, as we now upbraid the Irish. The writer of a pamphlet published in 1614,—"Tobias Gentleman, a fisherman and mariner,"—pointed to the great amount of wealth yearly taken out of His

Majesty's seas by the Hollanders, whereby they had grown rich and powerful, possessed of a great fleet, and were able to dictate terms to the Spaniards; whereas the English coasting people were poor, idle, and negligent, and constrained even to beg bread of the "plump Hollanders." Tobias was indignant at seeing the foreigners, whose industry and diligence he nevertheless praised, using our seas as a rich treasury, and drawing wealth from them as from a gold-mine. Six hundred Dutch busses, of some six score tons each, were employed in the herring-fishery along the British coast,—from the mouth of the Thames as far north as Shetland,—besides numerous others in the cod-fishery; protected by some twenty, thirty, and even forty ships of war to prevent their being pillaged by the Dunkirkers, who were the chief pirates of those times.

That these Dutchmen should come into our markets and sell us our own fish, carrying away great quantities of gold and silver, whilst English ships lay rotting, was a thing that, Mr. Gentleman thought, should not be borne. 'It is much to be lamented,' he said, "though we have such a plentiful Country and Store of able and idle people, that not one of His Majesty's Subjects is there to be seen, all the whole Summer, to fish or to take one Herring. but only the North-sea Boats of the Sea-coast Towns, that go to take Cods; they do take so many as they need to bait their Hooks, and no more. We are daily scorned by these Hollanders for being so negligent of our Profit and careless of our Fishing; and they do daily flout us that be the poor Fishermen of England, to our Faces at sea, calling to us and saying, *Ya* English, *ya zall or oud scone dragien*, which in English is this: *You* English, *we will make you glad to wear our old shoes.*" *

From this curious tract it would appear that much even of our commonest English industry is of modern growth; and that the herring fishery, which it might be supposed

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Harleian Miscellany,' iii. 378–90.

was indigenous in England, is as modern as most other branches of employment. Down to about the end of last century the only fishing was conducted close in-shore, the fishermen shooting the nets from their small cobles; and it was not until the year 1787 that the Yarmouth men began the deep-sea herring fishery.*

Another remarkable feature of those early times was the piracy which prevailed round the English coasts. The seas were as unsafe as the roads, and a system of plundering passing ships was as common as that of robbing mail-coaches. Sea-roving doubtless ran in the blood of the coast population, themselves the descendants of the pirate Northmen. There were many daring spirits amongst them, and when a bold leader started up and fitted out a ship to make a dash at Spanish galleons, or a descent on the French coast, he had never a lack of desperadoes to follow him—thorough-going seamen, equally ready to brave the storm and the battle—to face the hurricanes of the Atlantic in a cock boat, or to fight against any odds. Hence Scaliger, when describing the English of his day, said of them, "They make excellent sailors and pirates"—"Nulli melius piraticam exercent quam Angli." †

Drake sailed along the Spanish main, sacked the Spanish towns, burnt the Spanish ships, and carried off their gold, although no declaration of war had yet been made by Elizabeth against Spain. Drake's vessels were the property of private persons, who sent them forth upon adventure on the high seas; and there were not wanting others to follow his example, especially after war had been declared between the two countries. The records of the Corporation of London contain some curious entries relative to the fitting out of ships, which were sent to sea, for the capture of Spanish galleons and the subsequent division of the spoil. In 1593 we find a richly-laden carrack captured by Sir Walter Raleigh, and brought into the Thames a prize. On the 15th of November, in that year, a Committee was appointed "on behalf of such of the City Companies as had ventured in the late fleet, to join with such honourable personages as the Queen hath appointed, to take a perfect view of all such goods, prizes, spices, jewels, pearls, treasures, &c., lately taken in the carrack, and to make sale and division thereof."* It appears that about 12,000*l.* (then about four times the value of our present money) was divided amongst the Companies who had adventured, and that about 8000*l.* was similarly netted by them on a subsequent occasion.

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* 'An Historical Account of the Herring Fishery on the North-East Coast of England' (small pamphlet). By Dr. Cortis. Feb. 1858.

† Gongora, the Court poet of Spain, in his sonnet on the tomb of the Great Admiral Alvar Bazan, called "The Scourge of the English,' wrote these words in 1588:

> "Let all Hesperia weep in woe and pain,
> Heaven's wrathful sign in his sad loss displays,
> Whereby our *island foes*, no more afraid,
> Look up, and launch *their pirate craft* in vain."

And in his ode on the Armada, Gongora again says:

> "Doubt not, those English pirates soon shall stain
> The green and whitening main
> With dark and crimson gore."

Alvar Bazan was to have commanded the Armada, but died before it was ready for sailing.

Similar ventures were often made, both before and after Raleigh's time. In Richard II.'s reign, one Philpot hired a thousand men and sent them to sea, where they captured fifteen rich Spanish vessels.† Harry Page, of Poole, ravaged the coasts of Spain, France, and Flanders, bringing home the plunder of many churches, numerous prisoners, and prizes laden with rich cargoes.

But the piratical propensity was not only displayed against our continental neighbours, but by the seagoing population of one town against those of another. In 1342 Yarmouth and Hull sent out a piratical fleet against London and Bristol; and ports as near each other as Lyme and Dartmouth, in the adjoining counties of Dorset and Devon, waged deadly feud and strove to capture each other's vessels.*

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* 'Corporation of the City London Records,' Journal fol. 156.

† Roberts's 'Social History of the Southern Counties of England.'

The sailors of the Cinque Ports were at war with those of Yarmouth, and in Edward I.'s reign, regular safe conducts were granted to certain Cinque Ports vessels requiring to visit that port, as if it were an enemy's. The Yarmouth men were even at war with those of Lowestoft, Camden relating of them that "they often engaged their neighbours, the Lestoffenses, or men of Lowestoff, in sea-fights, with great slaughter on both sides."

Robert de Battaylo, of Winchelsea, plundered a passing ship belonging to some merchants of Sherborne; but the feat must have been regarded as creditable, for a few years later his townsmen chose him for their mayor. At the end of the sixteenth century three noted pirates—Hamilton, Twittie, and Purser—ravaged the coasts of the south-western counties. In 1582 Purser attacked the ships, both English and French, riding in Weymouth Harbour, and carried off a Rochelle ship of 60 tons. But Weymouth itself also sent out piratical vessels, which picked up many rich prizes.

Down even to the middle of the seventeenth century piracy was quite common along the Devonshire coast. The weakness of the royal navy is sufficiently obvious from the fact that Turks and Algerines sailed along the Channel, up the Severn, and into the Irish Sea, capturing ships; while the Dunkirk pirates assailed with impunity the east coast towns, from Dover to Berwick-upon-Tweed. The Emperor of Morocco was even *bribed* to cease from his piratical expeditions and to protect British trade; and the bribe continued to be paid until the year 1690. Sea-robbers were masters of the Channel as late as the reign of Charles I.†

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* Roberts's 'Social History of the Southern Counties of England,' p. 74.

† In 1634, the Lords of the Ad- ty wrote as follows to Capt. Thomas Ketelby:—"Have lately ved complaints out of the country of divers outrages

When piracy was at last put a stop to along the English coasts, the more desperate pirates took service under the Turks, while many more sailed away to the West India Islands and turned buccaneers.* Hugh Miller, in his autobiography, speaks of his great-grandfather, John Feddes, as "one of the last of the buccaneers;" and he states that the house in which he himself was born "had been built, he had every reason to believe, with Spanish gold."

Such being the early state of British shipping, there was very little need of harbours. The navigable tidal rivers were found amply sufficient for the accommodation of the shipping, then of comparatively small burden, by means of which trade was then carried on. London possessed a great advantage in her fine river, the Thames, up which the natural power of the tide lifted vessels of the largest burden into the heart of the land, and lowered others down again to the sea, twice in every twenty-four hours. The river served as harbour, dock, and depôt in one, and provided ample waterway, with abundant quay accommodation,

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lately committed in those parts by Turks and pirates, insomuch as the poor fishermen dare not out to sea, and the inhabitants are afraid of being taken in the night out of their houses. Further understand, that Ketelby being on the 17th May sent by Sir John Pennington, with the Garland and two Lion's Whelps, to scour the western coast and to suppress the Turks that lay between the Land's End and Scilly, he has neglected that important service, and [illegible] time in putting into [illegible] Sound and other Roads [illegible] hasten and scour the western parts, especially between Ushant, the Land's End and Scilly." ('Collection of State Papers,' 1634-5. Edited by J Bruce.) It was amidst such a state of things that King Charles required the tax of "Ship-money" to be levied Parliament would have granted him the money, but having chosen to levy it illegally, it shortly after led to "The Great Rebellion"

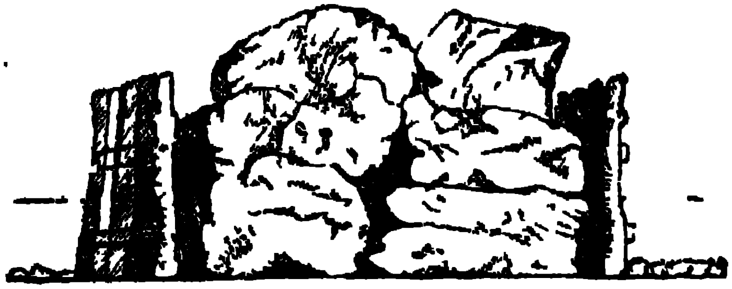
* Even in later times the prince of the Hebrides bore without scruple the title of "Arch-pirate" The Barbary states also afford examples of odious but not wholly savage communities, professing piracy as a trade, and the letters of marque of Europeans prove how easy, even to ourselves at the present day, is the suspension of the fundamental principles of our whole legal system, and the return to lawful private robbery. (Lappen-

which sufficiently served the purposes of trade down almost to our own day.

Among the early ports, Bristol ranked next in importance to London: it was also provided with a convenient river, the Avon, up which ships were floated by the tide to port. At the siege of Calais, in Edward III.'s time, Bristol furnished almost as many ships and mariners as London; and it went on increasing in importance down to the end of the seventeenth century. Liverpool was then scarcely known as a seaport, and, indeed, was little better than a fishing village. Before the art of engineering had advanced so far as to enable harbour walls to be built in deep water, the tidal rivers sufficiently answered the purpose of harbours. Hence London on the Thames, Bristol on the Avon, Hull on the river Hull, Chester (the principal shipping-port for Ireland) on the Dee, Gloucester on the Severn, Boston on the Witham, and Newcastle on the Tyne.

At Bristol the ships lay upon the mud at low water, the course of the river Froom having been turned, in early times, in order to make "a softe and whosy (oozy) harboure for grete shippes;" and the habit of lying on the mud made the Bristol ships so bulge and swell out, that until quite recently "a Bristol hog" could be recognised by the practised sailor's eye far off at sea. Bristol was only provided with floating docks at the beginning of the present century, long after Liverpool had overcome the difficulties of the currents in the Mersey, and provided for herself a system of docks, now considered superior to everything else of the kind in the world.

The ample line of the British coast, broken by innumerable deep-water bays and inlets, also afforded considerable convenience for the shipping of early times. The small size of the craft enabled them to be beached with ease, and the utmost that was done in the way of harbour works was to empty large stones roughly into the sea so as to form a breakwater or a pier at the harbour head. But the sea was found a fickle and dangerous neighbour, and those early works were often washed away. Mr. Roberts gives the rough representation, shown in the annexed cut, of the mode of constructing the ancient pier at Lyme Regis; and most probably the same method was pursued elsewhere.



Ancient Manner of constructing Piers

The rocks which lay upon the shore were floated over the line of the proposed sea-work by means of casks, and dropped into their places. Strong oak piles were then driven into the ground along either side of the rocks for the purpose of holding them together. Great reliance was placed upon timber, and especially upon oak.

The Cob or harbour at Lyme Regis * was so successfully put together in this way, that Queen Mary ordered the workmen to be impressed and forwarded to Dover, to execute a similar work for the protection of the harbour at that place. They were next employed at Hastings, where they reared a pier of huge rocks edgeways, but without timber. But the seas of the ensuing winter com-

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* The Duke of Monmouth, with followers, entered the port of Lyme in 1685. "That town," says Macaulay, "is a small knot of steep and narrow alleys, lying on a coast wild, rocky, and beaten by a stormy sea. The place was then chiefly remarkable for a pier, which in the days of the Plantagenets (?) had been constructed of stones, unhewn and uncemented This ancient work, known by the name of the Cob, enclosed the only haven where, in a space of many miles, the fishermen could take refuge from the tempests of the Channel."—'History of England,' i. 573. [First edition.]

pletely overthrew the structure; and again, in 1597, the workmen erected another pier, using much timber in cross-dogs, bars, and braces. The work was thirty feet high, "bewtyfull to behold, huge, invariable, and unremoveable in the judgment of all beholders;" but on the next All Saints day a storm upon a spring tide scattered the whole, and to this day Hastings remains without a stone pier.

Among the numerous fine natural harbours on the south coast were those of Portsmouth, Plymouth, Weymouth, Falmouth, and Dartmouth, all situated at the mouths of rivers or bays, as their names indicate. None of them had piers until a comparatively recent date, the only landing-places at Portsmouth and Southampton being on "the Hard." The Cinque Ports, on the coast of Kent, were mostly beach harbours, and were constantly liable to be choked up by the gradual movement of the shingle up Channel; so that Winchelsea, Romsey, and Hythe thus became completely lost. For the same reason Dover was always a port most difficult to be preserved. The shingle, rolling along the coast by the south-westerly winds, blocked up the port by a bank which extended from east to west, until the pent-up inland waters, collecting behind it, forced their way to sea, thus maintaining an opening more or less partial.

Various attempts were made to preserve Dover Harbour in early times, the most important improvements being those conducted by Sir John Thompson, master of the Maison Dieu in the reign of Henry VIII. He enclosed a small basin with a quay by driving two rows of piles into the sea bottom as far out as the Mole Rock, and filling in the interstices with blocks of stone and chalk. The stones were floated along shore from Folkestone, by means of empty casks, as at Lyme. It is said that not less than 50,000*l.* were expended on these works; but the imperfect manner in which they were constructed may be inferred from the fact that the sea very soon made several breaches in the wall and the pier, and the beach accumulated, as before, all round the bay, so that a boat drawing only four feet of water could scarcely enter the harbour.

Foreign engineers were then called in—amongst others, Ferdinand Poins, a Fleming, and Thomas Diggs, who had studied harbour construction in the Netherlands; and various additions were made by them to the works in the reigns of Elizabeth and James. The harbour was always, however, in danger of becoming silted up down to our own times; and the improvement of it formed the subject of repeated reports of Perry, Smeaton, Rennie, and Telford.

Along the east coast of England, the early harbours were few and bad. Thoresby relates that in his time (1682) Whitby, in Yorkshire, possessed a harbour formed by a rough quay projecting at the mouth of the river; but he adds that there was no other haven for ships between that place and Yarmouth, in Norfolk. Yarmouth has, like Dover, been the subject of much unavailing engineering, in consequence of the peculiar difficulties of its situation. It stands on the banks of the rivers Yare and Burr, from the former of which it received its name. It was always liable to be silted up by the sands which abound along shore. Nevertheless it continued to maintain some trade; and down to the time of Henry VIII. it was regarded as the most important maritime town along the east coast. But the channels leading to it were so liable to become choked up, that its prosperity was very irregular, and sometimes its navigation was all but lost.

The Yarmouth people were reduced to even greater straits than ordinary in the reign of Elizabeth, when they adopted the usual expedient of sending abroad for an engineer of reputation to recover their navigation; and Joyse Johnson, a celebrat man in his day, came over from Holland to direct the works. He caused a strong pier of piles to be formed, [illegible] had the effect of directing the current in such a man , in a north-easterly direction, as to give a temporary relief. The difficulty, however, was not surmounted, as we still find the inhabitants fighting against the sea-banks which hemmed in the port, during the reigns of James and Charles, and even during the Commonwealth; until eventually a south pier was formed, the continuation of which, in a fine curve, was carried up the river, and formed an extensive wharf, affording considerable accommodation and security for shipping. The original north pier was subsequently abandoned, and a new north pier was erected, on a plan chiefly intended to assist in warping ships into the harbour

Yarmouth Old Pier [By R P Leitch.]

Yarmouth long had a weather-beaten jetty—a great favourite with landscape painters—which extended into the sea on the eastern side of the town. On this site a jetty was built in 1560, with a crane at the end to facilitate the landing of goods. It was rebuilt in 1808, and became one of the principal landing-places on the east coast. Exiled sovereigns landed there to seek the shelter of England, and embarked there to seek the returning loyalty of their subjects. Nelson twice landed there, amidst enthusiasm, to receive the embraces of his countrymen.

The English docks, which are now the pride of English engineers, have for the most part been constructed during the present century. Liverpool set the example of dock-making at the beginning of last century, and it has continued to keep the lead of all the other towns and cities to this day. The first dock constructed in Great Britain was "The Old Dock" at Liverpool, under the powers of an Act passed in the eighth year of Queen Anne's reign,* when the population of the town was under 6000 in number. The Liverpool people were perhaps forced by necessity to make the dock. Sandbanks were closing up the Dee, and driving the little shipping there was from Chester to Liverpool. But the ships, when lying in the rapid current of the Mersey—which was also exposed to the heavy gales from the westward—could not easily be unloaded; and it was consequently found necessary to make inlets or docks along the strand, for the purpose of giving the ships shelter during the process of loading and unloading. Hence the first Act to provide Liverpool with a dock. It not only afforded 652 feet of quay space for the shipping, but it was shut in from the tides by means of dock-gates, and was consequently a floating dock. In 1760 the Salthouse Dock was opened, and still later the George's Dock. Dry docks were also provided, open to each tide, and these are now mostly used for the purposes of the coasting-trade.

The King's Floating Dock was opened in 1785, and the

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* 8 Anne, chap. 12: a Public Act. It was long before the Old Dock was finished; but we learn from William Enfield's 'Essay towards the History of Leverpool,' that it must have been opened by the year 1728.

Queen's Dock in 1789. Then followed the great Prince's Dock, which was opened in 1821, when the Old Dock, which could only accommodate smaller ships, was filled up, and the modern Custom House was erected on its site. The docks, which have since then been constructed in Liverpool, are of immense magnitude. They occupy about 300 acres, and are able to accommodate shipping of more than five millions of tons burden.

There was no public dock on the Thames until the beginning of the present century. There were two private docks: one, the Greenland Dock, for whaling ships; the other, Mr. Perry's dock, for the accommodation of East India ships. The Greenland Dock is said to have included the commencement of Canute's Trench, stated, on the authority of Stowe, to have been cut early in the eleventh century from thence to Battersea. Mr. Perry was a shipbuilder, who constructed his private dock at Blackwall, for the purpose of getting the East India shipping out of the river, and placing them, and the traffic they contained, under lock and key.

Before there were any public docks on the Thames, the merchandise was kept afloat in barges, for want of room to discharge it at the legal quays. An Indiaman of 800 tons could scarcely be delivered of her cargo in less than a month, and the goods had then to be lightered from Blackwall nearly to London Bridge. In addition to the rapid increase of foreign trade towards the end of last century, there was also a rapid increase in the coal trade.

A strong prejudice had long existed in London and elsewhere, as to the use of "sea-coal." Edward I. issued a proclamation against its use, and a man was actually hanged during his reign, for committing the crime of burning it within the limits of the City. But as the forests became consumed for the production of "charre coal" for domestic purposes, and for iron-smelting,* there was no alternative but to fall back upon the rich stores of coal found in the northern parts of England.

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* The destruction of the woods was a topic of lamentation with

Then it was that the Newcastle coal shipping-trade sprang into importance, and has ever since proved the principal nursery of our seamen. The fleets of colliers entering the Thames, added to the other shipping, caused a great throng of vessels in the river; and what with the coal-lighters and merchandise-barges,—which carried the goods and coal up the river,—and the warehouses and coal-yards on shore, it became a very crowded and often a very confused scene. The merchandise, borne from the vessels to the warehouses, became liable to serious depredations; and the losses from this cause, as well as the over-crowding of the river, at length led to the provision of floating docks at various points, and to a further vast development of the port of London.

The Thames was, for a long time, not only the harbour, but the great silent highway of the Metropolis. The city lay mostly along the banks of the river, and the streets and roads long continued so bad, that passengers desiring to proceed eastward or westward, almost invariably went by boat. There were also ferry-boats constantly plying

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the poets of the time. George Withers, in 1634, tells us with what feelings he beheld

> "The havoc and the spoyle,
> Which, ev'n within the compass of my dayes,
> Is made through every quarter of this Ile—
> In woods and groves, which were this kingdom's praise."

Stowe, also, in his 'Annals,' says: "At this present, through the great consuming of wood as aforesaid, and the neglect of planting of woods, there is so great scarcity of wood throughout the whole kingdom that not only the city of London, all haven towns, and in very many parts within the land, the inhabitants in general are *constrained* to make them fires of sea-coal or pit-coal, even in the chambers of honourable personages; and through necessity, which is the mother of all arts, they have of very late years devised the making of iron, the making of all sorts of glass, and burning of brick, with sea-coal or pit-coal. Within thirty years last, the nice dames of London would not come into any house or room where sea-als were burned, nor willingly t of the meat that was either or roasted with sea-coal fire." (Stowe's 'Annals,' by Horner. ndon, 1632, p. 1025.)

from side to side of the river, and so long as London Bridge presented the only means of crossing by coach or on foot, the number of persons daily using the ferries was necessarily very considerable. A horse-ferry plied between Lambeth Palace and Millbank, the tolls of which belonged to the Archbishop of Canterbury, and there was another across the river at Hungerford, both being rendered comparatively unnecessary when the second bridge was erected at Westminster. The extent of the river traffic may be inferred from the circumstance stated by Stowe, that in his time the Watermen's Company could at any time furnish twenty thousand men for the fleet. But as the streets of the metropolis were improved, as more bridges were built, and when the use of coaches had extended—against which the watermen strongly protested—their numbers rapidly diminished, until at length they have almost become extinct.

While the engineering and shipbuilding of England were in so backward a state, comparatively little use was made of the sea for the purposes of travelling. The state of the roads prevented travelling by land; the state of the ships prevented travelling by sea. Travelling by road was accompanied by the risk of highway robbery, and travelling by sea was accompanied by the risk of piracy and shipwreck.

At the present time, when a steamship can make the voyage between England and Australia with such regularity that you may count upon her arrival almost within three days, and when steamers of thousands of tons burden sail almost daily between New York and Liverpool, and their arrival may be depended upon to a day and almost to an hour, the loss of time in long and even short voyages, would now be regarded as something extraordinary. A passage *might* be made in a Leith smack between London and Edinburgh in four or five days; but during contrary winds, it might last for three or four weeks; and the smack might in the meanwhile be driven over to the coasts of Norway. At the beginning of the present century it took six weeks to bring the North Cork regiment of militia from Cork Harbour to Colchester.

There was a considerable difference in getting from London to the Continent in the old times and the new. The ancient Continental route used to be through Gravesend Manor, belonging to the Abbot of Tower Hill, who, "finding that by the continual recourse to and from Calais, the passage by water between London and Gravesend was much frequented, both for the great ease, good, cheap, and speedy transportation (requiring not one whole tide), made offer to the young King Richard the Second, that if he would be pleased to grant unto the inhabitants of Gravesend and Milton the privilege that none should transport any passengers by water from Gravesend to London but they only, in their own boats, then should they, of these two parishes, undertake to carry all such passengers, either for twopence each one with his farthell (a truss of straw) or otherwise, making the whole fare or passage worth four shillings." * To this proposal the King consented, and hence the route to and from the Continent long continued to be by Gravesend. Ambassadors to the Court usually took boat at Gravesend for London; and perhaps a finer entrance into the great Capital of the kingdom could not have been selected.

The comfort of the Long Ferry for the commoner sorts of people could not, however, have been very great. The passengers were required to bring with them their respective trusses of straw to lie on. They were also, when the tide was low, under the necessity of landing in the mud a mile or two short of their destination, and either wade their way to shore or pay for being carried thither on the

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* 'A Perambulation of Kent.' By William Lambarde, of Lincoln's Inn, Gent. London, 1656, p. 534.

backs of mud-larks. The boatmen only rendered themselves liable to a penalty, if they landed the passengers more than two miles short of their destination!

Fielding has left an account, in his 'Voyage to Lisbon,' of the tediousness and discomfort of voyaging, about the middle of last century. His ship was fixed to sail from opposite the Tower Wharf at a certain time, when Fielding, ghastly and ill, was rowed off to it in a wherry, running the gantlope through rows of sailors and watermen, who jeered and insulted him as he passed. The ship, however, did not set out for several days, and Fielding was compelled to spend the intervening time in the confines of Wapping and Redriff. The vessel at length sailed, and, reaching Gravesend, anchored for the night. Next evening they sailed for the Nore, and the day after that they anchored off Deal, and lay there for a week. It took four days more to beat down Channel to Ryde, where Fielding was landed in the mud fifteen days after his embarkation at the Tower; and a long, long time elapsed before the termination of his voyage at Lisbon.

When coaches began to run upon the improved road between London and Dover, passing by Blackheath and Dartford to Rochester and Canterbury, the principal part of the continental traffic was diverted from Gravesend, though the comfort of the journey does not seem to have been very much improved. Smollett gives a rather dismal account of his progress from London to Boulogne in 1763, which presents a curious contrast to the facilities of travelling by the modern Boulogne steam route. After tediously grumbling his way through Rochester and Canterbury, fleeced by every innkeeper on the road, he at last reached Dover in a very bad temper. He pronounced the place to be a den of thieves, where the people live by piracy in time of war, and by smuggling and fleecing strangers in time of peace. He did them the justice, however, to admit, that "they make no distinction between foreigners and natives. Without all doubt a man cannot be much worse lodged and worse treated in any part of Europe; nor will he in any other place meet with more flagrant instances of fraud, imposition, and brutality. One would imagine they had formed a general conspiracy against all those who go to or return from the Continent."

But Smollett's troubles had scarcely yet begun, as he found to his cost before he reached Boulogne. He sent for the master of the packet-boat—a comfortless tub, called a Folkestone cutter—and hired it to carry him across the Strait for six guineas, the master demanding eight. "We embarked," he says, "between six and seven in the evening, and found ourselves in a most wretched hovel. The cabin was so small that a dog could hardly turn in it, and the beds put me in mind of the holes described in some catacombs, in which the bodies of the dead were deposited, being thrust in with the feet foremost: there was no getting into them but endways, and indeed they seemed so dirty, that nothing but extreme necessity could have obliged me to use them. We sat up all night in a most uncomfortable situation, tossed about by the sea, cold and cramped, and weary and languishing for want of sleep. At three in the morning the master came down and told us we were just off the harbour of Boulogne; but the wind blowing off shore he could not possibly enter, and therefore advised us to go ashore in the boat."

Smollett went on deck, when the master pointed out through the spray raised by the scud of the sea where the harbour's mouth lay. The passengers were so impatient to get on shore, that after paying the captain and "gratifying the crew" (which was no easy matter in those days), they committed themselves to the ship's boat to be rowed on shore. They had scarcely, however, got half way to land, before they perceived a boat coming off to meet them, which the captain pronounced to be the French boat, and that it would be necessary to shift from the one small boat to the other in the open sea, "it being a privilege of the boatmen of Boulogne to carry all passengers ashore."

Smollett then proceeds:—"This was no time or place to remonstrate. The French boat came alongside, half filled with water, and we were handed from the one to the other. We were then obliged to lie upon our oars till the captain's boat went on board, and returned from the ship with a packet of letters: we were then rowed a long league in a rough sea, against wind and tide, before we reached the harbour, where we landed, benumbed with cold, and the women excessively sick. From our landing-place we were obliged to walk very near a mile to the inn where we purposed to lodge, attended by six or seven men and women, bare-legged, carrying our baggage. This boat cost me a guinea, besides paying exorbitantly the people who carried our things; so that the inhabitants of Dover and Boulogne seem to be of the same kidney, and indeed they understand one another perfectly well."*

The passage of the ferry between England and France continued much the same until a comparatively recent period; Fowell Buxton relating that as late as the year 1817 the packet in which he sailed from Dover to Boulogne drifted about in the Channel for two days and two nights, and only reached the port of Calais when every morsel of food on board had been consumed. Steam has entirely altered this state of things, as every traveller knows; and the same passage is now easily and regularly made four times a day, both ways, in about two hours.

The passage of ferries in the northern parts of England was equally tedious, uncomfortable, and often dangerous. In 'A Tour through England in 1765,' it is stated that at Liverpool passengers were carried to and from ferry-boats which plied three times a day to the opposite shore, "on the backs of men, who wade knee-deep in the mud to take them out of the boats."

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* Smollett's 'Travels through France and Italy.' Letter I., June 23rd, 1763.

Between Hull and Barton a packet plied once a day across the Humber, the travellers wading to the boats through a long reach of mud; but whether the voyage would occupy two hours or a day, no one could predict when embarking. If the weather looked threatening, the travellers would take up their abode at the miserable inn on the Barton side until the wind abated. Now the voyage is regularly and frequently performed every day, to and from New Holland, in less than half-an-hour.

The ferry of the Frith of Forth was also a formidable affair, and a voyage to Fife was often full of peril. The passage to Kinghorn or Burntisland was made in an open boat or a pinnace, and the boatmen usually waited, it might be for hours, until sufficient passengers had assembled to go across. The difficulty of passing the Forth ferries was experienced by Mr. Rennie as late as 1808, when returning across the Frith from Pettycur, where he had been examining the harbour with a view to its improvement for the packet-boats which plied between there and Leith. "The wind blew fresh," he says, "from about three points westward of south, and after beating about in the Frith for nearly three hours, we were obliged to return to Pettycur; and, to save time, I went round by Queen's Ferry," a place nine miles to the westward, from whence it was three miles across the Forth, and then other nine miles to Edinburgh; the distance directly across from Pettycur being only seven miles. This state of things, we need scarcely add, has been entirely altered by the facilities afforded by modern steam navigation.

The passage of the Bristol Channel was equally uncertain and dangerous. Gilpin gives a graphic account of the perils of his voyage across from Cardiff in 1770, in his 'Observations on the River Wye.' On descending towards the beach, he heard the ferryman winding his horn, as a signal to bring down the horses. The old ferry-boat was usually furnished with falling ends for the admission of cattle and heavy articles; and where the ferry was *across* a river, there was usually a chain passing along the side of the boat on pulleys, and fixed to each bank, by which it was hauled across. But from Cardiff to the other side of the Bristol Channel was several miles, and it was accordingly rather of the nature of a voyage. The same morning on which Gilpin crossed, the ferry-boat had made one ineffectual attempt to make the farther side at high water; but after toiling three hours against the wind, it had been obliged to put back.

When the horses were all on board, the horn again sounded for the passengers. "A very multifarious company assembled," says Gilpin, "and a miserable walk we had to the boat, through sludge, and over shelving, slippery rocks. When we got to it we found eleven horses on board and above thirty people; and our chaise (which we had intended to convert into a cabin during the voyage) slung into the shrouds. The boat, after some struggling with the shelves, at length gained the Channel. After beating about for near two hours against the wind, our voyage concluded, as it began, with an uncomfortable walk backwards through the sludge to high-water mark."

The passage of this ferry was often attended with loss of life when the tide ran strong and the wind blew up Channel. Moreover, the ferrymen were by no means skilful in the management of the boat. A British admiral, who arrived at one of these ferries, and intended to cross, observing the boat as she worked her way from the other side, declared that he durst not trust himself to the seamanship of such fellows as managed her; and, turning his horse, he rode some fifty miles round by Gloucester!

CHAPTER II.

BEACONS AND LIGHTHOUSES.

LIKE our docks and harbours, our lighthouses are among the youngest triumphs of modern engineering. Everything in England is young. We are an old people, but a young nation. Our trade is young; our mechanical power is young; our engineering is young; and the civilisation of what are called "the masses" has scarcely begun. Not a hundred years have elapsed since the best prize that could befall the barbarians of Devon and Cornwall was a rich shipwreck, and when false lights were displayed on shore to lure the passing vessel to its destruction.*

The lighting up of our coast by means of beacons and lighthouses for the purpose of insuring greater safety to ships approaching our shores by night, received very little attention in early times. So long as the mercantile navy was comparatively insignificant, and the amount of our foreign trade was but small, the lighting up of our shores after dark was of much less importance than it is now.

It was only when the commerce of the country began to develope itself—when our merchants sent out their vessels richly freighted to all parts of the world, and the sea was made a great highway for English trade and commerce—that it became a matter of absolute necessity, as well as of simple economy, to render the sea highway as safe as possible, by plantinglight houses upon all the dangerous rocks and headlands round the coast.

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* The inland people about Morte (North Devon) are "merciless to wrecked vessels, which they consider their own by immemorial usage, or rather right divine. Significant how an agricultural people is generally as cruel to wrecked seamen, as a fishing one is merciful. I could tell you twenty stories of the baysmen down there by the westward risking themselves like very heroes to save strangers' lives, and beating off the labouring folk who swarmed down for plunder from the inland hills." (Rev. Charles Kingsley, 'Prose Idylls.' 261.)

The idea of the Lighthouse is, of course, very old. The ancient commercial nations were familiar with its use. They erected a tower on some dangerous part of the coast, which was a landmark by day and a lighthouse by night. The Phœnicians, though they did not go far out to sea, but crept cautiously along shore, had marks by which they could easily sail along from one part of the shore to another. The Colossus of Rhodes is supposed to have been a gigantic brazen statue, surmounted by a hand bearing a lighted chauffer, for the guidance of the shipping entering the port.

The most distinguished of the early lighthouses was that erected on the Island of Pharos, at the mouth of the Nile. The island is now connected with the mainland, and forms the site of the modern Alexandria. From that early lighthouse, all subsequent ones built by the Romans were called after the name of the island—Pharos. Many were erected along the most frequented parts of the Latin coast. One of the most remarkable was that built by Claudius at Ostea, the chief port of ancient Rome. Pliny mentions those built at Ravenna, Pozziola, and Messina; and also the Pharos of the Isle of Capri, which was overthrown by an earthquake a few days before the death of Tiberius.*

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* It is also related that there were illegitimate lights shown by the barbarians of the coasts, who, like the Cornishmen, showed false lights for the purpose of luring passing ships to their destruction. It is not long since *wrecking* was a common practice along our south coast, as well as along the coast of Brittany, in France.

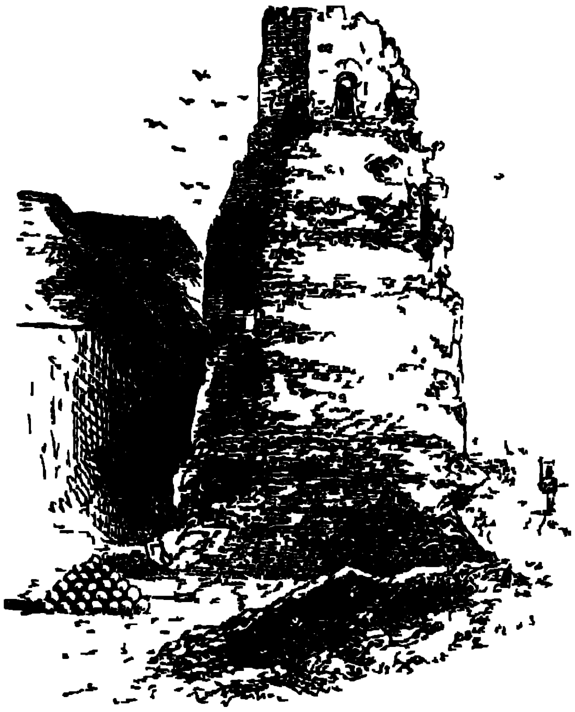
It is related of one of the Breton Counts, St. Léon, that when a jewel was offered to him for purchase, he led the dealer to a window of his castle, and, showing him a rock in the tideway, assured him that the black stone he saw was more valuable than al. the jewels in his casket. More valuable was the harvest of shipwrecks to that ancient Breton, than the much less gainful pursuits of honest industry.

The most important lighthouses erected by the Romans in the North of Europe were those erected on the heights above Boulogne, and on the heights above Dover. Their object was to light vessels passing across the Channel from one port to the other, and also those passing from the coasts of France to their stations at Portus Rutupiæ (now Richborough), near Sandwich or to Regulbium (now known as Reculvers) on the Thames, by way of the channel which then separated the Isle of Thanet from the mainland.

The tower at Boulogne is supposed to have been erected by Caligula. The original name was the *Turris Ardens*, but this eventually became corrupted into *Tour d'Ordre* It was repaired by Charlemagne in the ninth century, and continued to exist until the sixteenth century, when Boulogne was in the hands of the English. It was then surrounded by ramparts, and provided with artillery, which were used to command the town and the entrance to the port. Quarries have been dug out where it stood, the cliff has also fallen away, and the site of the Tour d'Ordre has long been destroyed.

From a description of the Pharos left by Claude Châtillon, engineer of Henry IV., it would appear that it was built about a stone's throw from the edge of the cliff, above and overlooking the high tower and the castle. The tower was octagonal in shape. At the base it was 192 feet in circumference, and about 64 in diameter. It was constructed of grey stone, with thin red brick, and yellow stones laid across at intervals. It was built in two stories, each retiring about a foot and a half inside the other, so that it had, in some measure, the form of a pyramid. Each story had an opening towards the sea, of about the size of an ordinary door. There is also supposed to have been a chamber to contain the light, above the two stories, which, however, had ceased to exist at the date at which it was examined by M. Châtillon.

The sister Pharos at Dover is of a similar character to that which existed at Boulogne. It is also of Roman build, as is apparent by the foundations being laid in a bed of clay, and by the Roman tiles, of the usual depth, laid in tiers across the work, and falling into each other like a half-dovetail, thereby rendering them close and compact. The Pharos occupies the highest point of the lofty rock on which the castle is built, and commands the English Channel as far as the eye can see. The coast of France, with Cape Grinez in the foreground, lies exactly opposite. The tower is octagonal without, and square within. At the base it is about 33 feet in diameter, and, originally, it may have been about 72 feet high. At the summit it has three round holes on the three exterior sides, evidently for the purpose of a look-out, or for showing a light seawards.


Pharos, Dover Castle.

Bede seems to have been under the impression that the Romans, during their long stay in Britain, erected lighthouses at different parts of the coast. Thus he interprets Streonshalh (the name of Whitby, in Yorkshire, in his time) into *Sinus Fari*, the bay of the lighthouse. The Romans had a road from York to Dunum Sinus, now Dunsley Bay, a few miles to the north-west of Whitby; and on an eminence in the midst of the village of Dunsley there still remain the ruins of a building which at one time may have been the guide-tower to the navigation, and thus gave rise to Bede's name of the Bay.*

Bede also relates that, before the Romans left, they built towers along the sea-coast to the southward, because there also the irruptions of the barbarians were apprehended, "and so they took leave of their friends, never to return again."† The southern coast of England was in those days subject to the frequent attacks of Frisian and Saxon pirates—and hence the appointment, during the Roman days, of a Duke of the Saxon shore—which shore included the opposite coasts of both France and England. The towers may have been erected along the English shore, as our Martello towers were erected some seventy years ago—and they may, possibly, have been used as lighthouses for the purpose of warning the people inland of the appearance of the pirates; but this is merely a supposition.

Many centuries elapsed after the Romans had left England, before anything further was done to light up the coasts by night. There was no necessity for doing so. The country had no commerce, no shipping, and was very thinly peopled. What civilisation the Romans had left was rapidly dying out. Then foreigners began to land from the opposite coasts. They planted themselves firmly on the soil, and made Britain their home. It took a long time for them to grow into a maritime people. They merely came across in boats from the nearest points of the opposite coast; and, with a fair wind, the voyage might be made in daylight within a few hours.

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* The passage in Bede (Hist. Eccles. Gentis Anglorum, i. cap. xi.) is as follows:—"Habitabant autem [Romani] intra vallum quod Severum trans insulam fecisse commemoravimus, ad plagam Meridianam, quod civitates, farus, pontes, et stratæ, ibidem factæ usque hodie testantur." The word "farus" has by some been transcribed as "fores" or "fana;" but the best writers make the proper reading to be "farus."

† Sed et in litore oceani ad Meridiem quo naves eorum habebantur, quia et inde Barbarorum irruptio timebatur, turres per intervalla ad prospectum maris collocant, et valedicunt sociis tanquam ultra non reversuri. (Bede, 'Hist Eccles. Gent. Angl.,' i. cap xii.)

It was not until the piratical Northmen began to cruise along our shores, that beacons and fire-towers began to be erected along the coasts, sometimes by the natives to warn the people inland against their arrival, and at other times by the pirates themselves to guide them on their way. The Norsemen knew every headland along the coast; and the names they gave them are retained to this day. From Dungeness and Grinez in the south, to Caithness in Scotland, and the Naze in Norway, the names of the headlands round the German Ocean are mostly of Norse derivation. The Northmen were among the first to navigate the Irish Sea, and along the west coast of England and the east coast of Ireland, they gave names to most of the projecting headlands along the coast.

Near the entrance to the river Boyne, there is a solid mass of masonry known as "The Finger," an ancient landmark, and probably a fire-beacon, erected by the Northmen, who then held possession of Dublin, of Wexford, of Waterford, and of Limeric and had extensive colonies settled in different parts of Ireland. On the opposite coast, in England and Wales, they had similar beacons and fire-towers. Near St. Ann's Head, at the northern entrance to Milford Haven, in Wales, there are the remains of an ancient beacon and lighthouse, which was all the more necessary to give light to the Norse ships entering the port,—as Milford Haven was the favourite piratical station of the Northmen, from which they made their descents upon Ireland, or on the Western Counties of England from Cornwall to Gloucester.

The Northmen had also settlements in the Isle of Man and the Northern Counties of England. At the entrance to Morecambe Bay there is a small island called the Isle of Walney, at the southern end of which is a place still called Peel. It was originally so called because of a pile or tower that served for a lighthouse to guide the Northmen on their voyages from the Isle of Man to Lancaster; and the neighbouring headland became known as Fire-ness or

Furness, which it retains to this day. Flamborough, on the eastern coast of England, was also in early times used by the Danes or Northmen as a lighthouse; and the name speaks of the rude fires of coal or wood that used to "flame" by night on that dangerous headland.* The Danes held a large area of nearly three thousand acres, enclosed by a formidable rampart—still called the *Danes' Dyke.* They most probably occupied it permanently, or, at all events, between the successive arrivals of their fleets; when it was necessary to light up the headland to direct their ships to the landing-place situated in the bay immediately under the Head.

South of Flamborough is a very dangerous part of the coast adjoining the northern entrance to the Humber. It is a narrow tapering neck of land, about two miles in length, over which the sea sweeps in high tides. The neck ends in Spurn Head. The first occupant of this place was a courageous hermit, who built a chapel to pray for poor mariners, and exposed a light in his windows to guide them up the Humber at night. Another anchorite, Richard Reedburrow, afterwards built a tower for a beacon, which is said to have been the first lighthouse built on that part of the coast.

In ancient times, fires were also lighted for the guidance of seamen, at Foulness, near Cromer, at Lowestoft-ness, and at Orford-ness—all Norse names. A long spit of land lies between the river Alde and the sea near Orford—extending from near Aldborough to Haversgate Island—which was always a source of danger to mariners. A lantern used to be hung out at a part of the narrow strip of land, still called the Lantern Marshes, where two splendid lighthouses have since been erected.

The first idea of a lighthouse, said Professor Faraday, is the candle in the cottage window, guiding the husband across the water or the pathless moor. But on Orford-ness a lantern answered the same purpose. The main point was the production of a steady light; and it mattered not whether it was given forth by a candle, a lantern, pitch-pots, coals, or oil. Wood was also frequently employed; but it was found too perishable. Lambarde says of the lights shown along the coast, that "before the time of Edward III. they were made of great stacks of wood; but about the eleventh yeere of his raigne it was ordained that in our shyre (Kent) they should be high standards with their pitch-pots."*

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* Rev. Isaac Taylor, 'Words and Places,' p. 393.

Many attempts were made to light up the south coast at the most dangerous places. Some six hundred years since, when Winchelsea—now several miles inland—was a seaport, Henry III. issued a precept commanding that every ship laden with merchandise going to that port for the two following years, should pay two pence for the maintenance of the light there, for the safety of sailors entering by night, unless it were shown that the Barons had been accustomed to maintain that light at their own cost.† It appears that the Barons were in certain cases required to maintain the fire-lights, and to receive the sum of two pence from each vessel, usually called "fire-pence."

One of the most dangerous parts of the south coast was Dungeness, consisting of a long low bank of shingle, running far out into the sea, and not easily discernible at night. It is not known when the first light was shown on this part of the coast; but Lambarde makes mention of its being lit up by beacons in the time of Edward III. Speaking of Dungeness, Lambarde says, "Before this neshe lieth a flat into the sea, threatening great danger to sailors. In the reign of Edward III. it was first ordered that beacons in this country should have their pitch-pots, and that they should no longer be made of wood-stacks or piles, as they be yet in Wiltshire and elsewhere." It has been observed, upon this passage, that the statement of Lambarde must imply that either a beacon was now first erected on the Ness Point, or that there had previously been one composed of wood, for which a pitch-pot was now introduced, as being considered preferable.*

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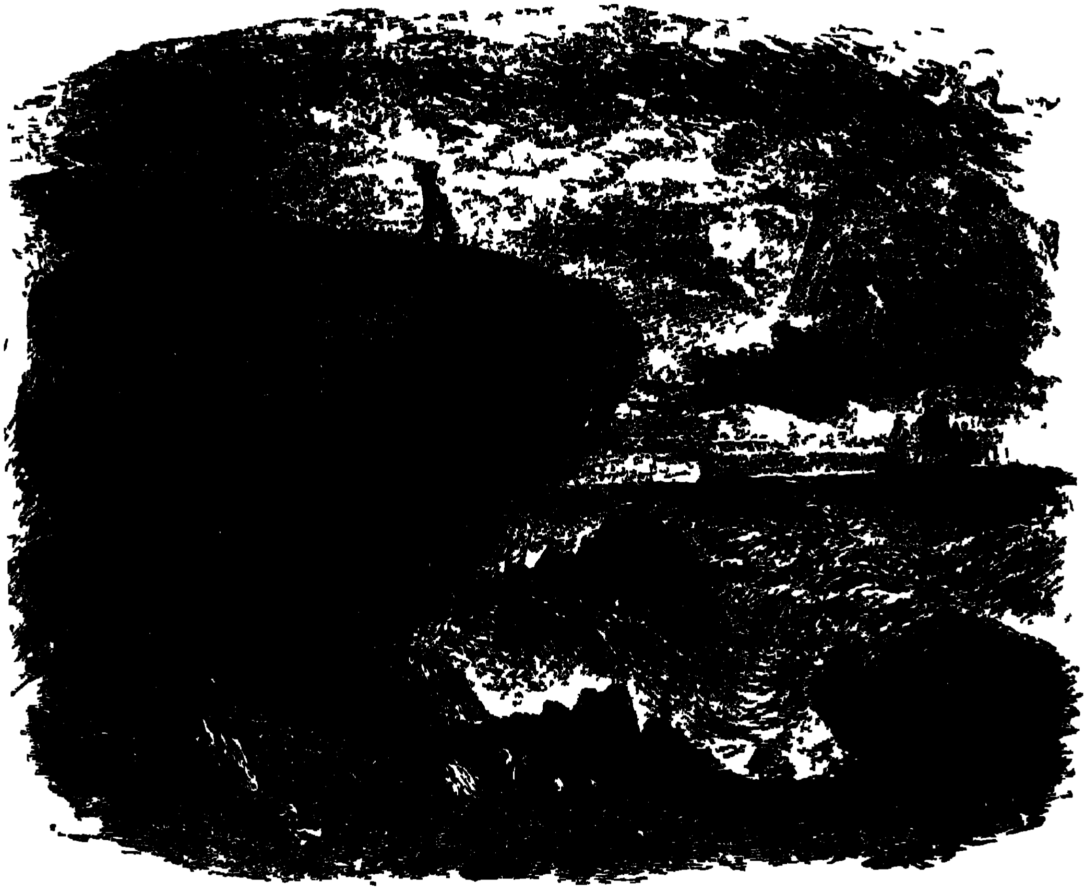
* William Lambarde, 'Perambulation of Kent,' p. 183.

† Rot. Patent, 45 Henry III. In an ordinance made in the reign of Henry III. for settling disputes between the Cinque Ports and the inhabitants of Yarmouth, it was declared that the bailiffs of the Barons of the Ports should receive the two pence from the masters of the ships, for sustaining the fires at the accustomed places, for the safety of vessels arriving by night, so long as they maintained the fires; but, if they failed to do so, the Provost of Yarmouth might receive the pence and maintain the fires. (Jenkes, 'Charters of the Cinque Ports,' 1728, p. 14.)



Old English Beacon.

[By R P Leitch. The Design of the Standard from Roberts's 'Social History']

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* Holloway's 'History of Romney Marsh,' p 119.—It has been stated that Dungeness Light was first projected by a Mr Allen, a

While these beacons were used to light up the coast for the benefit of mariners, they were also used for the purpose of alarming the nation when a foreign invasion was expected. When Richard II. succeeded Edward III. in 1377, fire-beacons were ordered to be established along the south coast, the keepers of which were enjoined to set them on fire so soon as they saw the enemy's vessels approach. England was at that time without a fleet, and notwithstanding that the hill of St. Catherine's in the Isle of Wight was furnished with a chantry and a lighthouse, where a priest was maintained to say mass and keep the light burning, the French, nevertheless, landed and carried away a great deal of spoil, as they afterwards did at Winchelsea, Plymouth, Dartmouth, and elsewhere.

Pitch-pots were not found to serve for coast-lights. In heavy storms, when lights were of the greatest value, the pitch-pots would either be blown out or drowned out, and then all would be darkness again. Coal was next introduced. It was set fire to, on an open chauffer, and fed from time to time by the lighthouse keepers. Wood continued to be used where coal was not available. Thus the Tour de Cordouan, off the south-western coast of France, long continued to be lit up by oak billets brought from the Gascon forests. But the English coast was mostly lit up by coal. In fact it is not so long since coal became disused. It was only in 1822 that the last coal fire, at Saint Bees, was extinguished. The last man who attended the coal beacon at Harwich—where the fuel was burnt in an open grate, with a pair of bellows attached—was alive only a few years ago.* The light-

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goldsmith of Rye, in the time of James I. But it will be observed that the Light existed long before that date. The present lighthouse was erected in 1792, at the sole expense of the Earl of Leicester after the model of the lighthouse built by Smeaton at Eddystone. Previous to that time, the light consisted of a raised platform, on which a pile of coals lay burning.

* Nall, 'Great Yarmouth and Lowestoft,' p. 721.

houses at Spurn Point, and on the Isle of May at the entrance to the Firth of Forth, also continued, until a recent period, to be lit up by coal-chauffers. The light, also, which these coal fires gave was very uncertain. When stirred, they emitted a bright blaze, and then sunk into almost utter darkness until again roused by the attendants.

A long time elapsed before anything practical was done to light up the coasts at night. The Trinity House was indeed established by Henry VIII. in 1515; but it was at first more of a monastic institution than a lighthouse association. It was denominated "The Brotherhood of the Most Glorious and Undividable Trinity." The brethren prayed for the mariners at sea, but they did not erect lighthouses. Their duties were enlarged by subsequent sovereigns. They had to appoint pilots for the Thames, collect dues for ballast, and erect lights and signals. They attended rather to the navigation of the Thames, than to the lighting of ships along the coast. The only step they took for the purpose of lighting up the coast, was the granting of leases from the Crown, for a definite number of years, to private persons willing to find the means of building and maintaining lights, in consideration of which, authority was given them to levy tolls on passing shipping.

The erection of lights became a matter of speculation as well as of political jobbing. A speculative man would propose to erect a lighthouse just as he might propose to sink a coal-mine. If there was a dangerous rock at sea, in front of a seaport, any man might propose to the Trinity House to erect a building there for the purpose of guiding ships, in which case he was allowed to levy dues on the ships that passed. Or, if he had political influence, he might use it for the purpose of obtaining a lighthouse. Thus a memorandum was found in the diary of Lord Grenville, to watch the king into a good humour, that he might "ask him for a lighthouse."

There was a combination of philanthropy with speculativeness, in erecting a lighthouse. The object was to save human life, though its net result was that it should pay its constructor a large profit. When a lighthouse was erected on the Smalls Rock in the Bristol Channel, it was through the instrumentality of Mr. Phillips of Liverpool, a member of the Society of Friends. His object was to erect, at his sole risk and expense, a work that should be "a great holy good to serve and save humanity." The lighthouse was erected at considerable risk, and it was a strange-looking barracoon when finished. It doubtless saved the lives of many seamen; but it also served the purposes of its erector, who derived a large income from it during his lifetime; and, after his death, his representatives obtained from the Trinity House not less than 170,000*l*. by way of compensation for handing it over to the Corporation.

There was another dangerous rock in the way of the shipping bound for Liverpool—the Skerries Islands, north-east of Holyhead. A privilege was granted to a private speculator to erect a lighthouse there; and the dues received by the owner were so large that the Trinity Board were compelled to give him 450,000*l*. for the rock and lighthouse, when they took it into their own hands! A wooden lighthouse was also erected in 1698 on the Eddystone Rock as a matter of speculation; but that was soon swept away by the sea.* The coasts of Cornwall and Devon were also lit up about the same period; for we are informed, in the Travels of the Grand Duke Cosmo in England about two centuries ago, that the Plymouth shipping "paid fourpence per ton for the lights which were in the lighthouses at night."†

We also find from the records of the Corporation of Rye, that a light was hung out from the south-east angle of the castellated building in that town, called the Ypres Tower, as a guide for vessels entering the harbour in the night-time, and that not being found sufficient, another light was ordered by the Corporation "to be hung out o' nights on the south-west corner of the church, for a guide to vessels entering the port. A beacon to rouse the inhabitants in case of invasion was also kindled in the old oak-tree still remaining in the neighbouring churchyard at Playden. A light-pot used to be hung out from the spire of old Arundel Church for the purpose of guiding vessels entering the harbour of Littlehampton after dark, and the iron support of the rude apparatus is still to be seen there.[*]

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* See 'Life of Smeaton.'

† 'Travels of Cosmo the Third Grand Duke of Tuscany, through England' (1668-9). London, 1821.

That lights were used for the guidance of ships may also be learnt from the practice which then prevailed among the wreckers along the Cornish coast of displaying *false* lights, and thus luring passing vessels to their destruction; the shipwreck season being long regarded as the harvest season in Cornwall. With the increase of navigation, the erection of lighthouses at the more dangerous parts of the coast became a matter of urgent necessity; and it was such necessity, as we shall afterwards find, which brought to light the genius of Smeaton.

Until the erection of the Eddystone Lighthouse by that engineer, the only stone lighthouse in Europe was the fine Tour de Cordouan, built on a flat rock off the mouth of the Garonne in the Bay of Biscay. It was finished and lit up more than two hundred and fifty years ago; and, though one of the earliest, it continues one of the most splendid structures of the kind in existence. It replaced a lighthouse founded by the English on the rock in 1362–71, while the Black Prince was Governor of Guienne.

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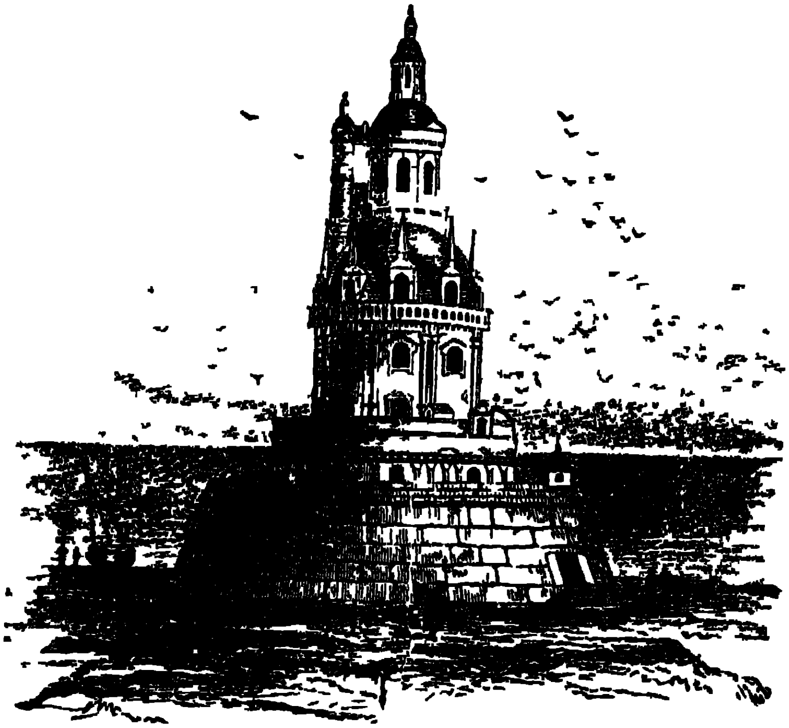
[*] The tower of Hadley Church, near Chipping Barnet in Middlesex, was similarly used in ancient times, but as a *land* beacon. The iron cage in which the pitch-pot was placed is still there. It is said that a lamp used formerly to be hung from the old steeple of All Saints, York, for the purpose of guiding travellers at night over the forest of Galtres, and the hook of the pulley by which the lamp was raised is still in its place. Lantern lights were also hung from the steeple of Bow Church, London, Stowe says, "whereby travellers to the City might have the better sight thereof, and not miss their way."

The present stone building was begun by Louis de Foix, one of the architects of the Escurial, in 1584, in the time of Henry III., and was continued all through the reign of Henry IV., being finally completed in 1611, in the reign of Louis XIII. Its height originally was 169 feet French; but in 1727 it was raised to the height of 175 feet French, or 186½ feet English. The building exhibits that taste for magnificence in construction which attained its meridian in France under Louis XIV. The tower does not receive the shock of the waves, but is protected at the base by a wall of circumvallation, which encloses the apartments for the attendants. It is not conical like the Eddystone, but is constructed in three successive stages, angular in the interior, and consequently more susceptible of decoration than the simple and solid structures of Smeaton, Rennie, and Stevenson.

The Tour de Cordouan is further memorable as the first lighthouse in which a revolving light was ever exhibited.



Tour de Cordouan.

CHAPTER III.

OLD BRIDGES.

In a country such as Britain, full of running streams, bridges form an essential part of every system of roads connecting the various districts of the kingdom with each other. So long as the population was scanty and the intercourse between different parts of the country was of a limited character, the necessity for bridges, by which the continuity of the tracks was preserved, was probably little felt. The shallow and broad parts of rivers, provided with a gravelly bottom, were naturally selected as the places for fords, which could be easily waded by men or horses when the water was low; and even in the worst case, when the waters were out, they could be crossed by swimming.

Towns and villages sprang up at these fordable places, along the main lines of communication, the names of many of which survive to this day and indicate their origin. Thus, along the line of road between London and Dover, there was first Deep Ford, now Deptford, at the crossing of the Ravensbourne—next Crayford on the river Cray—Dartford on the Darent—and Aylesford on the Medway, part of the pilgrim's road between the west of England and Becket's shrine at Canterbury. In all other directions round London it was the same. Thus, eastward, there was Stratford* on the Lea, Romford on the Bourne, and Chelmsford on the Chelmer. Westward were Brentford and Twyford on the Brent, Watford on the Colne, and Oxenford or Oxford on the Isis.* And along the line of the Great North Road, crossing as it did the large streams descending from the high lands of the centre of England towards the North Sea, the fords were very numerous. At Hertford the Maran was crossed, at Bedford the Ouse, at Stamford the Welland, and so on through the northern counties of England.

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* There are numerous bridges in England at places called Stratford or Stretford—literally the ford on the street or road, the ford being afterwards superseded by the bridge.

As population and travelling increased, the expedient of the Bridge was adopted, to enable rivers of moderate width to be crossed dryshod. An uprooted tree thrown across a narrow stream was probably the first bridge; and he would probably be considered an ingenious man who laid down a couple of trees, fixed upon them a cross-planking, and thus enabled foot-passengers and pack-horses to cross from one bank to the other. But these loose timber structures were very apt to be swept away by the rains of autumn, and the continuous track would again become completely broken. In a rough district, where rocky streams with rugged banks had to be crossed, such interruptions must necessarily have led to considerable inconvenience, and hence arose the idea of tying the rocky gorges together by means of stone bridges of a solid and permanent character.

The first of such bridges in Britain were probably those erected across the streams of Dartmoor. The rivers of that district are rapid and turbulent in winter, and come sweeping down from the hills with great fury. The deep gorges worn by them in the rocks amidst which they run, prevented their being forded in the usual way; and the ordinary expedient of bridging the gaps in the track by means of felled trees thrown across, was found impracticable in a district where no trees grew. But there was

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* Oxenford was the spot at which the Thames, then called the Isis, was most easily fordable for cattle.—H. Brandreth, Esq., in 'Archæologia,' vol. xxvii. 97.

Ancient British Bridge on Dartmoor [By Percival Skelton.

an abundance of granite blocks, which not only afforded the means of forming solid piers, but were also of sufficient size to be laid in a tabular form from one pier to another, so as to constitute a solid enough road for horsemen and foot-passengers. Hence the Egyptian-looking Cyclopean bridges of Dartmoor; a series of structures—most probably coeval with the building of Stonehenge—of the greatest possible interest.

One of the largest of these bridges is that crossing the East Dart, near Post Bridge, on the road between Moreton and Tavistock, of which a representation is given on the preceding page. Though the structure is rude, it is yet of a most durable character, otherwise it could not have withstood the fury of the Dart for full twenty centuries, as it most probably has done. The bridge is of three piers, each consisting of six layers of granite-slabs above the foundation. One of the side piers, by accident or design, has unfortunately been displaced, and the tabular slabs originally placed upon it now lie in the bottom of the river. Each of the table stones is about fifteen feet long and six feet wide, the whole structure being held together merely by the weight of the blocks.

There are other more perfect specimens of these Cyclopean bridges in existence on Dartmoor, but none of a size equal to that above delineated. For instance, there is one of three openings, in a very complete state, in the neighbourhood of Sittaford Tor, spanning the North Teign: it is twenty-seven feet long, with a roadway seven feet wide, and, like the others, is entirely formed of granite blocks. There is another over the Cowsic, near Two Bridges, presenting five openings: this bridge is thirty-seven feet long and four feet broad, but it is only about three feet and a half above the surface; nevertheless it has firmly withstood the moorland torrents of centuries. There is a fourth on the Blackabrook, consisting of a single stone or clam. We believe that no structures resembling these bridges have been found in any other part of Britain, or even in

Brittany, so celebrated for its aboriginal remains. The only bridges at all approaching them in character are found in Ancient Egypt,—to which, indeed, they bear a striking resemblance.

Although the Romans were great bridge-builders, it is not certain that they erected any arched stone bridges* during their occupation of England, though it is probable that they built numerous timber bridges upon stone piers. The most important were those of Rochester, Newcastle, and London. Not many years since, when a railway-bridge was being built across the Medway at Rochester, the workmen came upon the foundations of the ancient work in a place where no such foundations were looked for, and their solidity caused considerable interruption to the work. So at Newcastle, when the old bridge over the Tyne was taken down in 1771, the foundations of the piers, which were laid on piles of fine black oak, in a perfect state of preservation, were found to be of Roman masonry. Similar bridges were erected at different points along the lines of the Roman military roads wherever a river had to be crossed; and it is probable that the town of Pontefract (*Pons fractus*) derived its name from a broken Roman bridge in that neighbourhood, the remains of which were visible in the time of Leland.

It is not known when the English people began to build stone bridges, after the Roman bridges had become destroyed. The history of England was a blank for several hundred years after the Romans left. We know next to nothing of the people who occupied the country; we can only guess at the successive migrations of the foreigners who settled in it. The probability is, that at first they were, for the most part, barbarians, who neither built bridges nor repaired the roads which the Romans had left behind them. Civilisation recommenced with the Church. The early Churchmen were not only the first people who could read and write English, but they were the principal agriculturists, gardeners, and masons. They were the first church-builders, as they were also, probably, the first bridge-builders.

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* Mr. Wright is, however, of opinion that some of the Roman bridges in England had arches; and he says Mr. Roach Smith has pointed out a very fine semi-circular arched bridge over the little river Cock, near its entrance into the Wharfe, about half-a-mile below Tadcaster, on the Roman road leading southward from that town (the ancient Calcaria), which he considered to be Roman. The masonry of this bridge is massive, and remarkably well preserved; the stones are carefully squared and sharply cut, and in some of them the mason's mark, an R, is distinctly visible. The roadway was very narrow ('The Celt, the Roman and the Saxon,' 2nd Ed., p. 187.)

Thus, we hear of St. Swithin, Bishop of Winchester, building a bridge over the Itchin at that city in the ninth century. He planned the bridge, and caused it to be built at his own expense. As St. Swithin "had necessarily to go abroad upon spiritual matters, as ever, so in this instance, he cared for the common advantage of the citizens, and built a bridge of stone arches at the east gate of the city, a work which will not easily decay." *

Bridges were also constructed, most probably through the influence of the Churchmen, at Lincoln, Durham, and other ecclesiastical cities. These early bridges were useful, but not graceful. They resembled a long, low series of culverts, hardly deserving the name of arches, with intervening piers of greater thickness than the span of the arch they were built to support. They were a sort of stone embankments perforated by a multitude of small openings

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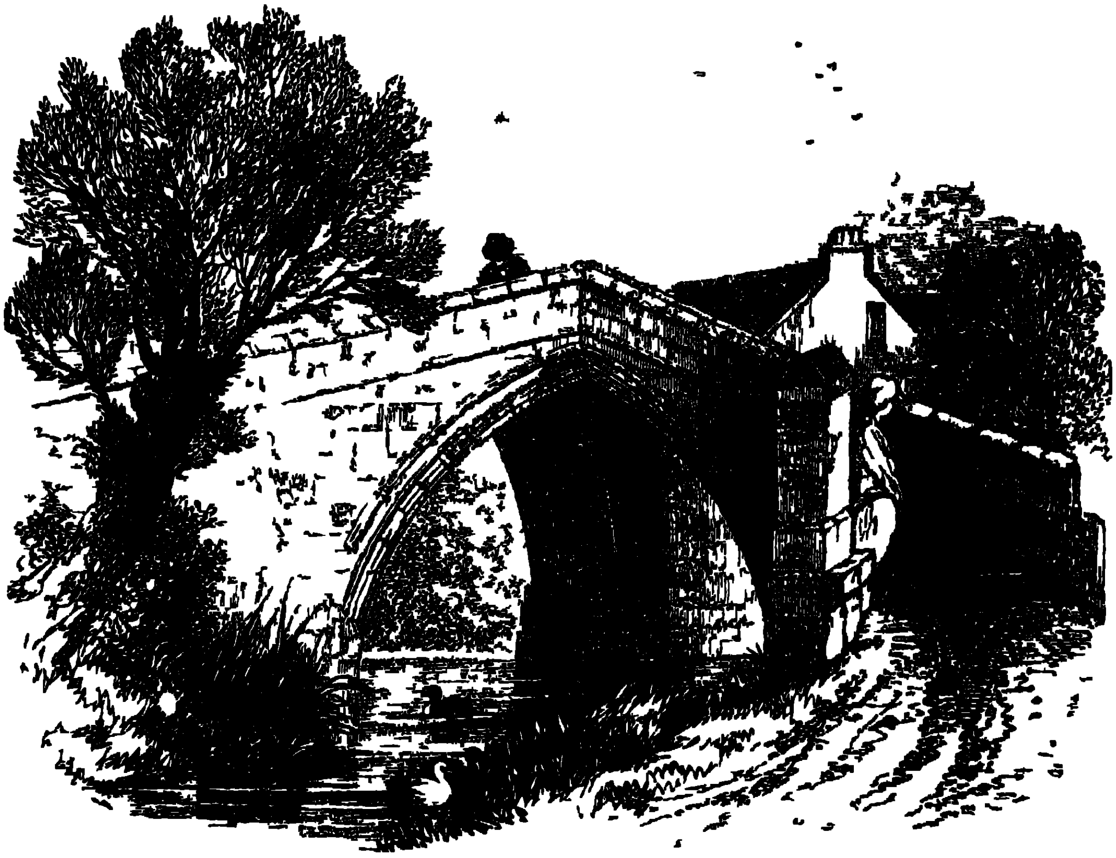
* In the 'Life of St. Swithin' (Arundel MSS., B. M., 169), it is stated:—"Unde factum est, ut necessitate exigente de spiritualibus ad forinseca exiens utilitati communi civium sicut semper et aliquando provideret, pontemque ad orientalem portam civitatis arcubus lapideis opere non leviter ruituro construeret."

The MS. is a 'Life of St. Swithin;' probably of the eleventh century.

The Life of St. Swithin in the 'Acta Sanctorum' (eleventh century); the Metrical Life (thirteenth century); and the Life in Caxton's Golden Legend, contain the above passage, or paraphrases of it.

to let the water through. The piers had thus very little more to support than their own weight. Quantity was substituted for quality, and mass for elegance.

An early bridge, which some allege to be the earliest arched stone bridge existing in England, is the singular-looking structure still standing in the immediate neighbourhood of Croyland Abbey, a few miles north of Peterborough. It has been conjectured that the bridge, which is triangular, was erected out of the offerings of pilgrims to the shrine of St. Guthlac, the saint of the Fens, as an emblem of the Trinity.* The bridge stands on three



Croyland Bridge. [From the 'Topographia Britannica.']

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* The famous bridge at Croyland is the greatest curiosity in Britain, if not in Europe. It is of a triangular form, rising from three segments of a circle, and meeting at a point at top. It

piers, from each of which springs the segment of a circular arch, all the segments meeting at a point in the centre. It is situated at the junction of the three principal streets of the little town, which was originally built on piles; and along those streets the waters of the Nene, the Welland, and the Catwater respectively, used to flow and meet under the bridge. Carrying out the Trinitarian illustration, each pier of the bridge was said to stand in a different county: one in Lincoln, the second in Cambridge, and the third in Northampton. The road over the bridge is so steep, that horses can scarcely cross it, and they usually go under it; indeed the arches underneath are now quite dry. This curious structure is referred to in an ancient charter of the year 943, although the precise date of its erection is unknown. On the south-west wing, facing the London road, is a sitting figure, carved in stone, very much battered about the face by the mischievous boys of the place. The figure has a globe or orb in its hand. It is supposed to be a statue of King Ethelbald, though it is commonly spoken of in the village as Oliver Cromwell holding a penny loaf!

The first ordinary road-bridge of which we have any authentic account is that erected at Stratford over the river Lea, several miles to the east of London. The road into Essex by the Old Ford across the Lea is noticed as early as the seventh century. It appears that the body of St. Erkenwald was stopped there by the flood, while being conveyed from the abbey of Barking, where he had died, for interment in London; and the body of the Saint was only conveyed across the river by the intervention of a

seems to have been built under the direction of the abbots, rather to excite admiration and furnish a pretence for granting indulgences and collecting money, than for any real use; for though it stands in a bog, and must have cost a vast sum, yet it is so steep in its ascent and descent that neither carriages nor horsemen can get over it. ('History and Antiquities of Croyland Abbey.' Bibliotheca Topographica Britannica, No. 11) miracle! Many lives were afterwards lost in crossing the Old Ford, and amongst those who narrowly escaped drowning was Maud, Queen-Consort of Henry I. Several of her attendants were drowned, while her Majesty herself was, to use Stowe's expression, "well washed in the water."

To prevent this great danger to travellers, the Queen directed two bridges to be built over the two branches of the Lea—one at Bow, the other at Channelsea, connected by a gravel causeway; and she bequeathed certain manors and a mill to the abbess of Barking for their maintenance and repair. The bridges were erected some time between the years 1100, when Maud became Queen, and 1118, the year of her death: and they are supposed to have been named "de Arcubus," or the Bows, because of their arched form. Stowe says, "the bridge (of Stratford-le-Bow) was arched like a bow; a rare piece of work, for before that the like had never been seen in England."

Notwithstanding the ample endowment of the bridges, and the additions made to it by successive benefactors, their repair seems to have been sadly neglected, and the approaches were often found impassable. The crowns of the arches became worn into deep ruts, and they must shortly have fallen in, had not one Hugh Pratt, who lived in the neighbourhood in the time of King John, contrived, by begging aid from the passers-by, to keep the structures in repair. His son continued the practice, and even obtained leave to levy tolls, amongst which we find the following: "For every cart carrying corn, wood, coal, &c., one penny; of one carrying tasel, two pence; and of one carrying a dead Jew, eight pence." * At a still later period, we find collections made in all the churches throughout the City, for the purpose of repairing Bow

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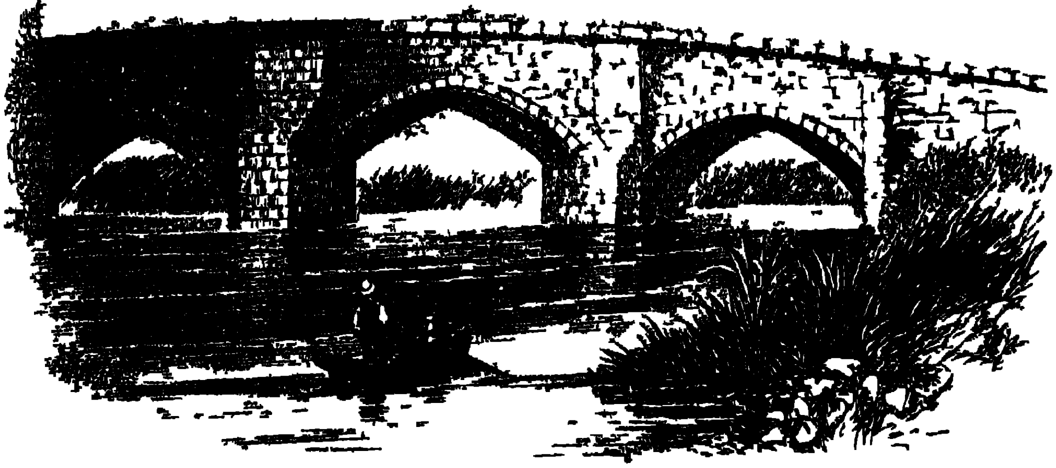
* Probably the last toll was imposed on the bodies of Jews, in progress of removal for interment in a Jewish burying-ground situated to the eastward of the bridge.

Bridge, as "a work of great necessity for the passage of victual unto the inhabitants;" and in the reign of Elizabeth we find a letter, signed by Burleigh, Lincoln, Sussex, and other Lords of the Privy Council, to the Corporation, acknowledging that such collection had been made by the free-will of the citizens, and was not to be drawn into a precedent for compelling the citizens at any future time to be at the cost of repairing the said bridge.



Old Bow Bridge. [From the 'Archæologia.'

Bow Bridge was unquestionably a structure of great utility, but though Stowe describes it as a rare piece of work, it possessed no great merit in an architectural point of view, as will be obvious from the above representation.

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* 'Corporation of the City of London Journals,' 21 fol. 58 b, 20th July, 1580.

This bridge, like most of the early structures, had large piers, occupying a great part of the waterway, and supporting small and low-arched openings, with high battlements for the enclosure of a roadway of the narrowest possible dimensions. The piers were provided with large angular projections, not only to divide the force of the current, but to admit of spaces for foot-passengers to retire into, and thus avoid danger from carriages and horsemen when passing along the narrow roadway. Indeed, its extreme narrowness, notwithstanding the attempts made to widen it, eventually led to the removal of the bridge, and the substitution of a new one of a single arch on the same site some twenty years ago.

The great convenience of bridges gradually led to their erection along most of the principal routes through the country. In the first place they superseded fords; and when the art of bridge-building had become more advanced, they superseded ferries—always an inconvenient, and often a dangerous, method of crossing rapid rivers. Many towns were named because of the bridge erected in their neighbourhood. Thus Bristol is only a corruption of Briegstow, the bridge-place, or the site where the river Avon was crossed by a bridge. Hence also Bridgenorth, Bridgewater, Brigg, and similar names of places.

The bridge brought the inhabitants of certain districts into immediate connection with those on the opposite bank of the river flowing between them, and enabled them freely to hold intercourse and exchange produce with each other; and the public advantages of this improved means of communication were found so great as to lead many benevolent and thoughtful men, in those early days, to bequeath large sums of money for the purpose of building and maintaining bridges, in like manner as public benefactors, in after times, left money to build and endow churches and hospitals. Yet popular tradition in some places attributes these structures to a very different origin.

Thus the fine old bridge of three arches over the river Lune at Kirkby Lonsdale, in Westmoreland, is said to have been the work of the devil.*

We have said that the religious orders early took in hand the erection and maintenance of bridges, and we owe to them some of the finest structures still extant, many others having been superseded by modern works. An order called the Brothers of the Bridge was founded by St. Benezet, the builder of the noble bridge at Avignon early in the thirteenth century; and the brethren spread into England, and went from one work to another, building bridges and chapels thereon, the provision of a bridge-chantry characterizing nearly all their early structures in this country. Indeed, the architecture of the early bridges in many respects resembled that of the early cathedrals. From the point at which the piers rose above the level of the stream, ribs of stone usually spanned the openings from one pier to the other, precisely similar to the Gothic arching of cathedrals and vaults of chapter-houses; and it is most probable that the bridges and cathedrals were built by the same class of workmen.

One of the finest of such bridges was that erected by Abbot Bernard over the Trent at Burton, until recently the longest in England. It was 1545 feet in length, and consisted of thirty-four arches, built of squared free-stone,—a most useful and substantial structure. Another old bridge of the same period is that over the Wensum at Norwich, still called Bishop's Bridge, a singular-looking old building of patched-up stone and flint, erected in 1295. It consists of three arches, inside of which are some grotesque heads and remains of old ornamental work. Fairs used formerly to be held on it at Easter and Whitsuntide, as was the practice on several other old bridges. At Leeds the weekly cloth-market was held on the bridge at the foot of Briggate, some of the old arches of which are still to be seen; the clothiers being summoned to assemble by the ringing of a bell in the old bridge-chapel, when they exposed their cloth for sale on the parapets. But the bridge was so narrow, and the market caused so great an obstruction, that at length a special cloth-hall was built, to which the clothiers removed about the end of last century.

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* How this tradition could have originated does not appear. The bridge is very lofty, and of excellent workmanship. It consists of three semicircular ribbed arches, the centre one being much higher than the others. The roadway however, inconveniently narrow, like all the old bridges. It is evidently of the Norman period, and the erection of a very clever architect.

The erection of Wade Bridge over the river Camel, in Cornwall, is an example of the origin of many of these structures in early times. The benevolent vicar of Egloshayle, lamenting the number of lives that were annually lost in crossing the ferry, determined to raise a fund sufficient to build a bridge; and success crowned his efforts. It was erected in 1485, and claimed the distinction, with Burton Bridge, of being the longest in England. It consisted of seventeen arches, and, though recently widened and repaired, stands firmly upon its foundations to the present day. The vicar must have been a man of great energy, for it is recorded of him that he designed the bridge and worked diligently upon it until it was finished.* At his death he left an endowment of 20*l.* a-year towards its maintenance.

Rochester Bridge was an important part of the great highway between London and the Continent, and a Roman timber roadway on stone piers formed part of the ancient Watling Street. The bridge long continued to be of timber, and we find Simon de Montfort burning it down in 1264. Twenty years later, having been repaired in the interval, it was seriously damaged by the breaking up of the ice, the force of which, rushing down the Medway, carried away several of the piers. It was patched up from time to time until the reign of Edward III., when the gallant Sir Robert Knolles, who had raised himself by his valour from the rank of a private soldier to that of a commander in the royal army during the wars in France, returning to England, and determining to leave behind him some useful work by which his name should be held in kindly remembrance by his countrymen, resolved upon the erection of an arched stone bridge over the Medway, and it was accordingly built at his charge and made over by him to the public. It was completed in the fifteenth year of the reign of Richard II., and was considered one of the finest bridges at that time in England. It had eleven arches, resting on substantial piers, the foundations of which were blown up, not many years since, by the Royal Engineers, at a considerable expenditure of gunpowder.* A chapel was afterwards erected by Sir John Cobham at its east end, where collections were made in the usual manner for maintaining the structure. But it appears that the moneys thus collected had been insufficient, and the bridge shortly fell into decay; for, about a century after its erection (in 1489), we find John Morton, Archbishop of Canterbury, adopting the extraordinary expedient of publishing a remission from purgatory for forty days, and from all manner of fines, to such persons as should give anything towards the repairs, as the bridge had by that time become very much broken.

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* It is said he had great difficulty in securing foundations, owing to the sandy nature of the ground, until he had recourse to "packs of wool." The same tradition was handed down as to London Bridge. The meaning is, that the vicar raised the requisite money by means of a tax on wool.

Bishop-Auckland Bridge over the Wear, and Newcastle Bridge over the Tyne, were similar structures, maintained by the voluntary offerings collected by the priests who ministered in the chantries. The chapel was invariably dedicated to some patron saint. That on old London Bridge was dedicated to St. Thomas, on Bow Bridge to St. Catherine, and others were dedicated to St. Nicholas, the patron saint of sailors. The chapels were exceedingly picturesque objects, and were often highly decorated. They were erected over one of the piers, about the centre

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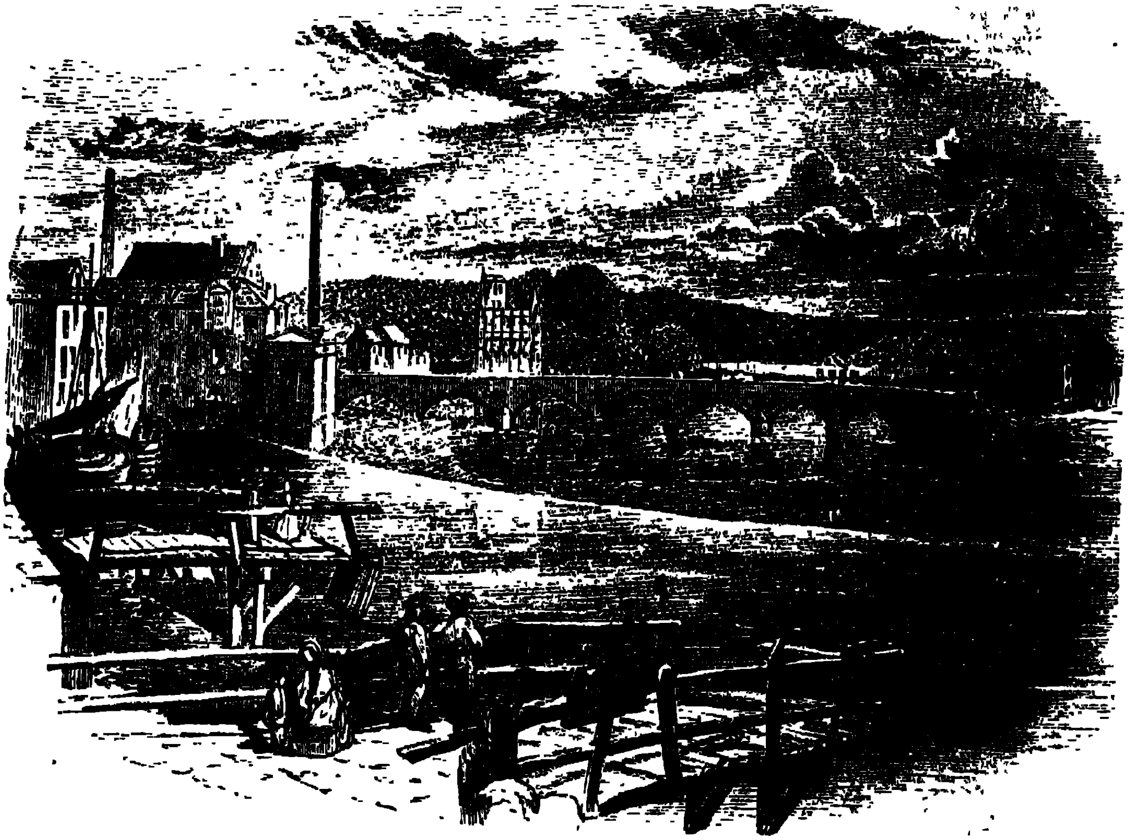
* The foundations seem to have been obtained in the then usual manner, by throwing loose rubble and chalk into the river, and surrounding the several heaps with huge starlings, which occupied a very large part of the water-way, and consequently presented a serious obstruction to the navigation of the Medway



Wakefield Bridge and Chantry.

[By E. M. Wimperis, after an original Drawing by T. Sutcliffe.]

of the bridge, elongated for the purpose; and a brother stood at the door to receive the offerings of the passers-by towards the repairs of the bridge and the support of the services in the chantry. There was a chapel on a bridge in Droitwich, Worcestershire, through which the high turnpike-road passed until within a few years past; and the congregation sitting on the one side of the King's way, heard the preacher from his pulpit on the other.* Nearly all these old bridge-chapels have perished, but a beautiful specimen has happily been preserved in the chantry on Wakefield Bridge, of which the preceding cut is a representation.

This bridge is supposed to have been built by Edward Duke of York, afterwards Edward IV., in memory of his father and followers who fell at the battle of Wakefield during the wars of the Roses. It was richly endowed, that prayers might be offered up there for the souls of the slain, and especially of poor little Rutland. However this may be, the bridge chantry at Wakefield, which has recently been renovated in excellent taste, and is still used for evening service, is one of the most beautiful and interesting of these ancient structures. The entrance to the chapel is directly from the roadway, and it stands upon an elongated pier obviously erected for the purpose, and forming part of the original structure. The bridge itself has undergone many changes, in order to adapt it to the improved modes of travelling. When chaises, stage-coaches and waggons came into general use, the old erections were found altogether inadequate for the traffic. They were very narrow,† and often very steep; and though they had been well enough adapted for the foot-passenger, the horseman, and the pack-horse convoy, many of them did not admit of sufficient width for the convenient passage of wheeled vehicles. The picturesque gateways at the ends of old bridges—such as existed over the Ouse at York and the Monnow at Monmouth, as shown in the next cut—were also found to be a great obstacle to stage-coach

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Sir J. Cullum's 'History of Hawsted.'

† De Quincey, in his 'Autobiographic Sketches,' says he has known of a case, even in the nineteenth century, where a post-chaise of the common narrow dimensions was obliged to retrace its route for fourteen miles on coming to a bridge in Cumberland built in some remote age when as yet post-chaises were neither known nor anticipated, and, unfortunately, too narrow by three or four inches to enable the vehicle to pass.

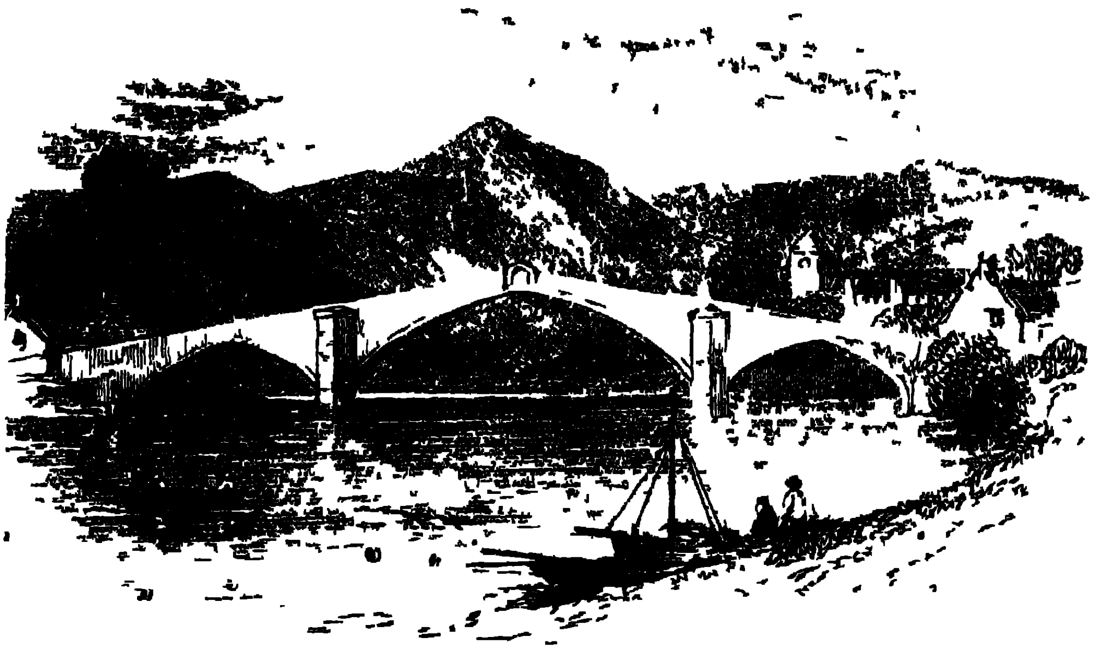
travelling. The arched gateways did not admit of the passage of a coach without danger to the outside passengers; and where it was not found practicable to turn the thoroughfare another way, they were shortly demolished. The bridges themselves were widened and enlarged; and though in many cases, as at Wakefield, the old piers were included in the new work, the original picturesque character of the bridge was in a great measure destroyed.

Monmouth Bridge

Notwithstanding the increased necessity for such structures, the art of bridge-building seems to have fallen into decay and become almost a lost art until about the middle of last century; and whilst many of the erections of the Brothers of the Bridge continued to stand firm on their foundations, as they had done for centuries, the bridges of more modern construction were liable to be swept away by the next winter's flood.

The only mode of securing foundations was the clumsy one of throwing loose stones promiscuously into the bed of the river, so as to find their own bearing, and then, on the top of these loose stones, the stonework of the starlings was erected. The piers were built up on the foundations thus rudely formed; but they were constantly liable, as may be readily imagined, to be unsettled, undermined, and carried away by the rapid flow of the river.

No architect of eminence devoted himself to bridge-building; and although Inigo Jones furnished the design for the bridge of Llanrwst, over the Conway in Wales, in 1634, it was a work of a comparatively unimportant character, and the only one of the kind on which he seems to have been employed. In the plan of this bridge the pointed arch is no longer adopted, but three segmental arches, the middle of which is of the span of fifty-eight feet. The road way approached the horizontal line, and was of sufficient breadth to accommodate carriage traffic. On the whole, the design was of a very modern character, and was probably adopted, to a considerable extent, as a model by succeeding bridge-builders.



Inigo Jones's Bridge at Llanrwst. [By E. M. Wimperis.]

The work, however, seems to have been so badly done, that it was shortly after found necessary to rebuild one of the arches; and to this day the bridge is known as "the shaking bridge," * as it does not stand very firmly on its foundations. The people of the locality consider this a merit, as it certainly is a curiosity, and they attribute the shaking of the bridge to the "very nice principles on which it is built." But that the bridge should shake or rock could have formed no part of Inigo Jones's design, and that it stands at all must be attributable mainly to the fact of its foundation being upon a rock, which cannot be undermined and washed away.

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* A tourist in North Wales says:—"While standing on the bridge, admiring the beautiful scenery, two or three men came and asked in broken English 'whether I would like to have a shake.' On inquiry I found that the bridge will strongly vibrate by a person striking his back forcibly against the parapet of the centre arch." (Parry's 'Cambrian Mirror,' p. 134.)

CHAPTER IV.

Old London Bridge.

The erection of the old stone bridge across the Thames at London, was the most formidable enterprise of the kind undertaken in England during the Middle Ages. It was a work of great magnitude and difficulty, in consequence of the rapid rise and fall of the tides in the river, but it was one of essential importance as connecting the fertile districts lying to the south of the Thames, directly with the population of the metropolis.

As in all similar cases, the ferry (where the river could not be forded) preceded the bridge. The Romans first established a trajectus on the Thames, thus connecting their station in London with their military road to Dover. Dion Cassius makes mention of a bridge over the Thames at the time of the expedition of the Emperor Claudius in A.D. 44. It may have been of boats, or it may have been constructed on piles, for the Romans frequently constructed bridges of this sort in order to maintain their communications.

After the departure of the Romans the bridge ceased to exist, and the Saxons continued to pass across from one side of the river to the other by means of a ferry. The name of one of the masters of the ancient ferry has descended to us in a tradition of a singular character.* This was John Overy, the father of the foundress of St. Mary's church in Southwark. The property in the ferry, with its revenues, having become the possession of the adjoining college of priests of St. Mary's, they determined on the bold enterprise of erecting a bridge of timber across the river. The first mention of this structure is contained in the laws of Ethelred, where the tolls of vessels coming to Billingsgate *ad pontem* are fixed and defined. William of Malmesbury states that, in 994, Sweyn, the Danish king, when sailing up the river to the attack of London, ran foul of the bridge with his ships, and in the contest which subsequently ensued between the Londoners on the north and the Danes on the south of the river, the bridge was destroyed.

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* The tradition is, that John Overy rented the ferry of the City, and what with hard work, great gains, and penurious living, he became exceedingly rich. His daughter Mary, beautiful and of a pious disposition, was sought in marriage by a young gallant, who was rather more ambitious of being the ferryman's heir than his son-in-law. It is related that the ferryman, in one of his fits of usury, formed a scheme of feigning himself dead for twenty-four hours, in the expectation that his servants would, out of propriety

It seems, however, to have been repaired by the time that Canute sailed up the Thames with his fleet several years later; for, finding the bridge to be an obstacle in his way, he adopted the bold expedient of cutting a wide ditch or canal from near Dockhead, at Redriff, through the marshes on the south side of the river, westward to the lower end of Chelsea Reach, through which he drew his ships and completed the blockade of the city. Not long after, in 1091, the timber-bridge was entirely swept away by a flood; but the provision of so great a convenience was found indispensable, and William Rufus levied a heavy tax for its rebuilding.

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fast until after his funeral. He was accordingly laid out as dead, his daughter consenting to the plan, against her better judgment. The servants, instead of fasting as the ferryman had anticipated, broke open the larder and fell to banqueting, until the dead man could bear it no longer, but rose up in his winding-sheet to rate them. At this, one of the ferry-men, thinking it was the devil who stood before them, seized the butt-end of a broken oar and brained John Overy on the spot. Mary Overy's gallant, hearing of the news, rode up to town in all haste from the country; but his horse stumbling he was thrown, and "brake his neck." On which, Mary Overy is said to have founded the church which still bears her name, and made over her possessions to the college of priests which was there and then established.

Again, in 1097, a new timber-bridge rose upon the ruins of the old one; but fifty years later we find it destroyed by a fire which broke out in a tenement near London Stone, and burnt down all the houses eastward as far as Aldgate, and from thence to the south bank of the river, including the Bridge. It was again patched up; but it was found so costly to maintain the wooden structure, and it ran so much risk from fire and floods, that it was eventually determined to build a bridge of stone upon nearly the same site; and the work was accordingly begun by one Peter, the chaplain of St. Mary's, Colechurch, in the Poultry, in the year 1176.

One of the most important considerations in building a bridge across a deep and rapid river is the security of its foundations. Comparatively few of the older bridges failed from the unskilful construction of their arches, but many were undermined and carried away by floods where the foundation of the piers was insecure. The period at which Old London Bridge was built is so remote, and the records left of the mode of conducting the work are so meagre, that it is impossible, even were it desirable, to give any detailed account of the building. Some writers have supposed that the whole course of the river was diverted in the line of Canute's canal above referred to, and that the bed of the Thames was thus laid dry to enable the foundations of the piers to be got in. This expedient has frequently been adopted in building bridges across streams of moderate size; but it is scarcely probable that it was employed in this case. When the foundations of the old bridge were taken up, it was ascertained that strong elm piles had been driven deep into the bed of the river as closely as possible, and large blocks of stone were cast into the interior spaces.

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[*] Stowe was of this opinion. See his 'Survey.' See also Dr. Wallis to Pepys, Oct. 24th, 1699, 'Pepys's Diary.' v. 375. For much antiquarian information on this and all other points relating to the structure, see Thompson's 'Chronicles of Old London Bridge,' a singularly curious book.

Long planks, strongly bolted, were placed over the piles, and on these the bases of the piers were laid, the lowermost being bedded in pitch, whilst outside of all was placed the pile-work, called starlings, for the purpose of breaking the rush of the water and protecting the foundation piles.

Another statement was long current—that London Bridge was built on wool-packs—arising from the circumstance that a tax was levied by the King upon wool, skins, and leather, passing over the bridge, towards defraying the cost of its construction. The bridge was in a measure regarded as a national work, and for more than two centuries after its erection, tribute continued to be levied upon the inhabitants of the counties nearest the metropolis for its maintenance and repair. Liberal gifts and donations were also made with the same object, until at length the Bridge Estates yielded a large annual income.

Old London Bridge, 1209.

Not less than thirty-three years were occupied in the erection of this important structure. It was begun in the reign of Henry II., carried on during that of Richard I., and finished in the eleventh year of King John, 1209.

Before then, however, the aged priest, its architect, died, and he was buried in the crypt of the chapel which had by that time been erected over the centre pier. At his death another priest, a Frenchman, called Isenbert, who had displayed much skill in constructing the bridges at Saintes and Rochelle, was recommended by the King as his successor. But his appointment was not confirmed by the Mayor and citizens of London, who deputed three of their own body to superintend the finishing of the work –the chief difficulties connected with which had indeed already been surmounted.

The bridge, when finished, was a remarkable and curious work. That it possessed the elements of stability and strength was sufficiently proved by the fact that upon it the traffic of London was safely borne across the river for more than six hundred years. But it was an unsightly mass of masonry, so far as the bridge was concerned; although the overhanging buildings, extending along both sides of the roadway, the chapel on the centre pier, and the adjoining drawbridge, served to give it an exceedingly picturesque appearance. One of the houses adjoining the drawbridge was dignified with the name of Nonsuch House: it was said to have been constructed in Holland and brought over in pieces, when it was set up without mortar or iron, being held together solely by wooden pegs.

The piers of the bridge were so close, and the arches so low, that at high water they resembled a long low series of culverts hardly deserving the name of arches. The piers were of various dimensions, in some cases almost as thick as the spans of the arches which they supported were wide. The structure might be compared to a very strong stone embankment built across the river, perforated by a number of small openings, through which the water rushed with tremendous force as the tide was rising or falling, the power thus produced being at a later period economised and employed in some of the arches to work water-engines. The bridge had not less than twenty arches, including the drawbridge, some of them being too narrow to admit of the passage of boats of any kind.

This great obstruction of the stream, at a point where the river is about the narrowest, had the effect of producing a series of cataracts at the rise and fall of each tide, so that what was called "the roar of the bridge" was heard a long way off. The feat of "shooting the bridge" was in those days attended with considerable danger, and lives were frequently lost in the attempt. Hence prudent passengers, who took a boat for down river, usually landed above the bridge and walked to the nearest wharf below, where they again embarked. The more venturous risked "shooting the bridge," and thus boats were frequently swamped and their passengers drowned. In 1428 John Mowbray, second Duke of Norfolk, when passing under one of the arches, ran his boat upon the pile-work, and had very nearly perished; but leaping on to one of the starlings, he was then hauled up to the bridge by ropes let down to him for the purpose. The risk attending this operation of shooting the bridge explains the old proverb, that "London Bridge was made for wise men to go over, and fools to go under."

Perhaps the most singular feature of the old bridge was its upper platform, consisting of two rows of houses with a narrow roadway between, the chapel and drawbridge, and the turreted battlements at either end. The length of the roadway was 926 feet, and from end to end it was enclosed by the lofty timber-houses, which were held together by arches crossing overhead from one range to the other and thus keeping the whole in position. The street was narrow, dark, and dangerous. There were only three openings between the houses on either side, provided with balustrades from which a view of the river and its shipping might be obtained, as well as of the rear of the houses themselves, which overhung the parapets and completely hid the arches from sight.

On the centre pier was the chapel with its tower, and at the ends of the bridge were the gatehouses, on which the grim heads of traitors and unfortunate partisans were stuck upon poles until a comparatively recent period. Hentzner, a German traveller, counted above thirty heads displayed upon them as late as the year 1598.

The drawbridge was another curious feature. It occupied the fourteenth arch from the north end, and provided an opening of about thirty feet. It was used for purposes of defence as well as to provide for the passage of masted ships. When Jack Cade was told of the army marching against him, Shakespeare makes him say, "Let's go fight with them; but first go and set London Bridge on fire." But Cade's project having failed, his head was taken off and placed upon a pole, amongst those of other traitors, over the southern gatehouse, with his face looking towards Kent.

Old London Bridge. [By E. M. Wimperis, after the Painting by Claude de Jongh.

The bridge was also used as a place of public punishment. Persons found guilty of practising witchcraft were compelled to do penance there. No less a personage than Eleanor Cobham, Duchess of Gloucester, was exposed upon the bridge in 1440, for the alleged crime of witchcraft.

The bridge had a long history and many vicissitudes. It had scarcely been completed ere the timber-houses upon it were consumed by a fire, and the bridge was thus at once stripped of its cumbrous load. But, as the revenues required for its maintenance and repair were in a great measure derived from the rental of the houses, which let for high sums, they were shortly after erected in even more cumbersome forms than before, and were for a long time principally inhabited by pin- and needle-makers.

At a very early period the bridge showed signs of weakness. Before it had stood a hundred years, a patent was issued by Edward I., authorising its speedy repair, in order "to prevent its sudden fall and the destruction of innumerable people dwelling thereon." Tolls were authorised to be taken—for every man crossing, a farthing; for every horseman, a penny; for every pack carried on a horse, one half-penny. There was not a word of vehicles, which did not as yet exist. The repairs done to the structure do not seem to have been of much effect; for in 1281 five of the arches, with the buildings over them, were carried away by a flood following a thaw, and the repairs had to be begun again on a more extensive scale than before. At a subsequent period Stowe's gate, tower, and arches, at the Southwark side, fell into the river.

After repeated patching, the bridge nevertheless continued to hang together for several centuries longer. It witnessed the processions of priests, the jousting of knights, the march of Kentish rebels, the triumphal march of Henry V. into the City after the battle of Agincourt, the funeral procession of the same monarch when borne to his royal tomb in Westminster Abbey, and the entrance to the metropolis of his successor after being crowned King of France at Notre Dame. Generation after generation of toiling men and women passed over the bridge, wearing its tracks deep with their feet, and sometimes moistening them with their tears. Still the old bridge stood on, almost down to our own day; for we shall find in the lives of Smeaton and Rennie, that these eminent engineers, amongst others, were called upon from time to time to direct its repair; until at last the old structure, which had served its purpose so long, was condemned and taken down, and the magnificent New London Bridge was erected in its stead.

It was long before any second bridge was built over the Thames near London. The advantages derived from the current of traffic passing through the City from a district extending for fifty or sixty miles on all sides of London, were felt to be of such importance that the citizens would not readily part with them. Bridges were regarded as the best feeders of towns and cities, and wherever one was erected, all the avenues by which it was approached became speedily converted into streets of valuable houses. At the two ends of the Thames Bridge were London and Southwark; at Tyne Bridge, Newcastle and Gateshead; and at the Medway Bridge, Rochester and Strood. But London was extending westward with such rapid strides, and the population of Westminster as well as Lambeth had so much increased, that the provision of an additional bridge for those districts came to be regarded as a matter of absolute necessity.

An attempt was made with this object in the reign of Charles II., but the project was vigorously resisted by the citizens of London. They waited upon his Majesty in state, and implored him to oppose the measure; and, on his compliance with the petition, their expression of gratitude towards him was as great as if he had delivered the City from a famine, or a plague, or a great fire, or some such overwhelming calamity. It is not improbable that the citizens secured his Majesty's support by the offer of money, which he very much wanted at the time: for we find from the records of the Common Council, of date the 25th October, 1664, that upon advancing by way of loan, the sum of 100,000*l.* to Charles II., the citizens took occasion to thank his Majesty in the following terms for preventing the erection of the new bridge at Westminster:—

"And withal to represent unto his Majesty the City's great sense and apprehension of, and most humble thanks for, the great instance of his Majesty's good and favour towards them expressed in preventing of the new bridge proposed to be built over the river of Thames betwixt Lambeth and Westminster, which, as is conceived, would have been of dangerous consequence to the state of this city."*

A few years later, in 1671, a similar project was attempted, and a bill was brought into the House of Commons to enable a bridge to be erected over the Thames as far west as Putney. But the Corporation of London was again up in arms, protesting against the establishment of *any* bridge which should enable the traffic to pass from one side of the river to the other without going through the City. The debate on the subject is exceedingly curious, as read by the light of the present day. Mr. Love declared the opinion of the Lord Mayor to be. "that if carts were to go over the proposed new bridge, *London would be destroyed.*" Sir William Thompson opposed it because it "would make the skirts of London too big for the body," besides producing sands and shelves in the river, and affecting the below-bridge navigation, which would cause the ships to lie as low down as Woolwich; whilst Mr. Boscawen opposed the bill, because, if conceded, there might be a claim set up for *even a third bridge*, at Lambeth, or some other point.† The bill was thrown out on these grounds by a majority of 67 to 51; and for nearly a hundred years more, London had no second bridge, notwithstanding that the old structure was so narrow that there was not room on it for two carts to pass each other! Since that time, however, twelve bridges have been thrown across the river between Putney and the City, and London is not yet destroyed! Indeed the cry still is for more bridges.

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* 'City of London Records,' jor. 15, 423.

† 'Debates of the House of Commons, from the Year 1667 to 1691.' Collected by the Hon. A. Grey. London, 1769.

The second bridge was built in 1738-50, nearly opposite the palace of Westminster. During the many centuries that had elapsed since old London Bridge had been erected, the science of bridge-building had made but little progress in England. The principal structures were of wood. Trees, merely squared, were laid side by side, at right angles with the stream, supported on perpendicular piles, the roadway being planked over and covered with gravel. Old Battersea Bridge was an example of the primitive structures by means of which many of our wide rivers long continued to be crossed. Few were built of stone and these, of a comparatively rude kind, were principally situated upon the main lines of road; but they were usually liable to be swept away by the first heavy flood. During the period referred to, however, the science of construction had made great progress in France, and from the practice of French engineers our best models continued for some time longer to be drawn. Hence, when the sanction of Parliament was at length obtained for a second bridge to be built across the Thames, Labelye, the French engineer, a native of Switzerland, was employed to design and execute the work.

It will have been observed that the chief difficulty with the early bridge-builders was, in securing proper foundations for their piers. A common practice was to sink baskets of small dimensions, full of stones, in the bed of the river, and on these, when raised above water, the foundations were laid. But where the bottom was composed of loose, shifting material, such as sand, it will be obvious that a firm basis could scarcely be secured by such a method. The plan adopted by Labelye, though considered an improvement at the time, was even inferior to the method employed by Peter of Colechurch in founding the piers of old London Bridge in the thirteenth century. For, clumsy though the latter structure was, it stood more than six hundred years, whilst Westminster Bridge had not been erected a century before it exhibited signs of giving way; and it is already destroyed.

Labelye's method of founding his piers was as follows. He had a sufficient number of large caissons, or water-tight chests, prepared on shore, of such form as to fit close alongside of each other. They were then floated on rafts over the spots destined for the piers, where they were permanently sunk. The top of each caisson, when sunk, being above high-water mark, the masonry was commenced within it, and carried up to a level with the stream, when the timber sides were removed and the pier was left resting firmly on the bottom grating. The foundations were then protected by sheet-piling, that is by a row of timbers driven firmly side by side into the earth all round the piers.

Westminster Bridge was originally intended for a wooden bridge, but the design was subsequently altered to one of stone, Labelye considering it necessary to have a great weight of masonry in order to keep his caissons at the proper level. To add to this weight, the engineer added a lofty parapet, which Grosley a French traveller, gravely asserted was placed there for the purpose of preventing the Londoners from committing suicide!

Not many years after Westminster Bridge had been opened, the London Common Council, in order to facilitate the passage of traffic across the Thames as near to the centre of the City as possible, applied to Parliament for powers to construct a bridge at Blackfriars; and the requisite Act having been passed, the works were commenced in 1760, and finished in 1769. The architect and engineer of Blackfriars Bridge was Robert Mylne; and a noble piece of masonry it was. The principal new feature in this structure was the elliptical arch,* which Mr. Mylne was the first to introduce into England.

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* The disadvantage of the semi-circular arch was that, though self-contained, it necessarily led to a great rise in the road over the

The innovation gave rise to a lively controversy at the time, in which Dr. Johnson took part,—in opposition to Mr. Mylne, and in support of his friend Gwyn, who was the designer of a rival plan. Boswell, in his 'Life of Johnson,' defends the design of Mylne, and adds, "it is well known that not only has Blackfriars Bridge never sunk either in its foundation or in its arches, which were so much the subject of contest, but any injuries which it has suffered from the effects of severe frosts, have been already, in some measure, repaired with sounder stone, and every necessary renewal can be completed at a moderate expense."

This was written in 1791, only twenty years after the bridge had been opened; and, though it may have been true then, it is so no longer. When the numerous heavy piers of old London Bridge—which acted as a dam across the river—had been removed, the low-water mark above-bridge fell *five feet*. The velocity of the unimpeded tide, sweeping up and down the Thames twice in every twenty-four hours, and the consequent increased scour along the bed of the river, soon began to grind away the foundations both of Blackfriars and Westminster Bridges; and they exhibited the unsightly appearance of numerous props and centerings to prevent the further subsidence of their foundations. Hence Labelye's bridge at Westminster, and Mylne's bridge at Blackfriars, have since been pulled down, in order to make room for newer bridges.

Robert Mylne, the engineer above referred to, was the descendant of a long line of Scotch masons and architects.

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bridge, which was thus steep at both sides. By means of the flat elliptical arch this disadvantage was obviated, and more water-way was afforded with less rise in the bridge. But greater science was required to construct bridges of this sort, as the strength mainly depended upon the abutments, which bore the lateral pressure. When the span was extensive, and the arches of considerable flatness, the greatest care was also required in the selection of the stone, which must necessarily be capable of resisting the severest compression.

The originator of the family was an Aberdeen man, who erected some of the principal churches and towers in that city, some three hundred years ago. His son was master mason to James VI.; he built a bridge over the Tay at Perth, which was swept away by a spate; and executed many other works, which were more successful. His son, and son's son, were also master masons. The latter rebuilt the cross at Perth, which had been destroyed in Oliver Cromwell's time for the purpose of building the Citadel. The cross has since been demolished as a hindrance to traffic.

Robert Mylne, the architect who built Blackfriars Bridge, was lineally descended from the master mason of James VI. In his youthhood he travelled abroad, and joined the Academy of St. Luke at Rome. He remained there five years, and received the chief prize in the highest class of architecture. After the building of Blackfriars Bridge, he was appointed surveyor of St. Paul's Cathedral; and at his death he was buried by the side of Sir Christopher Wren.

Mr. Mylne also held the office of engineer to the New River Company, in which he was succeeded by his son, and afterwards by his "son's son."

CHAPTER V.

WILLIAM EDWARDS, BRIDGE BUILDER.

THE difficulties encountered by the early bridge builders cannot be better illustrated than by a brief history of the life of William Edwards, architect of Pont-y-Prydd a remarkable work erected at Newbridge, in South Wales, about the middle of last century.

Edwards was born in 1719, in a small farmhouse in the parish of Eglwysilan, in Glamorganshire. His father died when William was only two years old; but his mother, who was an industrious, well-doing woman, kept on the farm, and piously and virtuously brought up her family. William's literary culture was confined to Welsh, which he could read and write from his early youth; but as he grew older he also learnt to read and write English, though more imperfectly. He had the character of being obstinate, stubborn, and self-willed in his boyhood, qualities which, under the guidance of virtue and piety, became developed into inflexible courage and resolution in his manhood. Until eighteen years of age he was regarded as a wild, headstrong fellow, with little promise of good in him; but he was gradually tamed and disciplined by hard work, and as he grew older he became thoughtful and sedate even beyond his years.

Edwards's first ordinary employment was common farm-work; but at the same time he was a diligent self-educator, taking lessons in arithmetic from a neighbour in the evenings. It happened that, in the ordinary course of affairs, he had occasion to repair the dry-stone walls about the farm. He took particular pleasure in this kind of work, and very soon became remarkably handy at it; but he always longed to do better. Some masons having come into the neighbourhood to build a smithy, Edwards would occasionally leave his farm-work and take his stand in the field where the masons were employed, eagerly

William Edwards. [By M. Morgan.]

watching them while they worked. He admired the way in which they handled their tools and prepared the stones for the building. One thing that he particularly noted was the way in which they dressed the rough blocks by means of the pointed end of the mason's hammer. He tried to do the same, but failed, his hammer-point not being steeled. He then inquired and ascertained the cause of his failure, and went to a smith and had a steeled point added to his hammer. With this he succeeded in dressing his stones much more neatly and quickly than he had been able to do before.

Practice and application, and the desire to excel, even in dry-stone wall building, inevitably carry a man onward; and Edwards soon became so expert in this sort of work, that he was extensively employed in repairing and building dry-stone walls for the neighbouring farmers. His walls were observed to be so neat, so firm, and so serviceable, that he was everywhere in request, and his earnings were regularly added to the common stock of his mother and brothers, who carried on the business of the farm. He began to consider himself fitted for something better than continuing this rough sort of work; and he thought that, instead of being a mere builder of dry-stone walls, he might even undertake to become a builder of houses.

An opportunity occurred of erecting a little workshop for a neighbour, and Edwards acquitted himself so well, that he gained much praise for his skill. Thus proving his ability in small things, he was shortly entrusted with the execution of works of greater importance. He had scarcely reached the age of twenty-one when he was employed to build an iron forge at Cardiff, and while carrying on the work he lodged with a blind man, named Rosser, by trade a baker. Rosser knew the English language, which as yet Edwards did not; and, what was more, the blind man could teach it to others. The young mason determined to take lessons of his landlord; and such was his assiduity and perseverance during his leisure hours, that he very shortly contrived to master the new language.

When he had completed his contract, which he did to the entire satisfaction of his employers, he regularly entered upon the business of a house-builder on a considerable scale, and very shortly there was not a building of any magnitude or importance in the neighbourhood—whether it were a mansion, a mill, or an iron forge—which he was not willing as well as competent to undertake.

During his leisure he took great pleasure in studying the ruins of Caerphilly Castle, near to where he lived. This castle was once the largest in the kingdom, next to Windsor, and its ruins are still of great extent, covering an area of about thirty acres. Its walls are of prodigious thickness, and its leaning tower has stood for centuries, inclining as much as eleven feet out of the perpendicular, held together principally by the strength of its cement. This old castle was the college in which Edwards studied the principles of masonry; and he himself was accustomed to say that he had derived more advantage from wandering about the ruins, observing the methods adopted by the

Ruins of Caerphilly Castle.

ancient builders, the manner in which they had hewed dressed, and set their stones, than from all the other instruction he received. It was while employed in erecting a mill in his own parish that he first applied the knowledge he had gained by studying the ruins of Caerphilly, in the construction of an arch. The mill was finished to admiration, and professional builders pronounced Edwards's arch to be an excellent piece of masonry.

Employment now flowed in upon him, and when any work of more than ordinary difficulty was proposed, application was usually made to William Edwards. Hence, in 1746, when it was proposed to throw a bridge over the river Taff, he was employed to build it; and though he was only twenty-seven years old, and had not yet built any bridge, he had the courage at once to undertake the work. The bridge was built of three arches, in a style superior to anything of the kind that had been erected in the neighbourhood; the stones were excellently dressed and closely jointed; the arches were light and elegant, and supposed to be sufficiently substantial for the duty they had to perform, and as a whole the erection was much admired, and greatly added to the fame of its builder.

It would appear, however, that Edwards had not sufficiently provided for the passage of the floods, which in certain seasons rush down from the Brecknock Beacon mountains with great impetuosity. Above Newbridge several rivers of considerable capacity, such as the Crue, the Bargold Taff, and the Cynon, besides numberless brooks descending rapidly from the high grounds, contribute to swell the torrent so as to render it almost irresistible. The piers of Edwards's new bridge unfortunately proved a serious obstruction in the way of a heavy flood which swept down the valley about two years and a half after the bridge had been completed. Trees were torn up by the roots and carried down the stream, lodging athwart the piers, where brushwood, haystacks and field-gates, becoming firmly stuck amongst their branches, choked up their arches and fairly dammed the torrent. The waters rapidly accumulated above the bridge and rose to the parapets; the sides of the valley being steep, left no room for their escape, and the tremendous force finally swept away arches and piers together, carrying the materials far down the river.

This destruction of his first bridge was doubtless a terrible blow to the builder, who was bound in sureties to maintain it for a period of seven years. But worse even than the loss of his time and labour was the failure of his design, the most distressing of all things to the man who takes a proper pride in his calling. He resolved, however, to fulfil his contract, and began the building of a second bridge of only one arch, to avoid the defect which had proved the ruin of the first.

This second bridge, without piers, was a much more difficult work than the first, in consequence of the wide span of the arch, which was not less than 140 feet, the segment of a circle of 170 feet in diameter. No such extensive span had yet been attempted in England; and even on the Continent, where the science of bridge-building was much better understood, the only bridges of larger span were of ancient construction, chiefly Roman. Michael Angelo's beautiful bridge of the Rialto, at Venice, was the largest span attempted in modern times, and its width was only about 100 feet.

The result of Edwards's daring experiment proved its extreme difficulty. He succeeded in finishing the arch, but had not added the parapets, when the tremendous pressure of the masonry over the haunches forced them down, the light crown of the bridge sprang up, the key stones were forced out, and a second time the labour of Edwards was lost, and his masonry lay a ruin at the bottom of the river. Yet not altogether lost; for by failure he learnt experience, dearly bought though it had been.

The undaunted man determined to try again. Twice he had failed, yet he was not utterly defeated in his resources. He would try a new expedient, and he believed he should eventually succeed. Fortunately his friends believed in him too, for they generously came forward and helped him

Pont-y-Prydd. [By Percival Skelton.

with the means of building his third bridge, which proved a complete success. The courage and skill of Edwards were crowned at last.

The plan which he adopted of more equally balancing the work and relieving the severe thrust upon the haunches, was to introduce three cylindrical holes or tunnels in the masonry at those parts of the bridge. The same plan is found to have been adopted in some of the ancient bridges, and Perronet, the great French engineer, not only formed such tunnels over the haunches, but occasionally in the piers themselves. Where Edwards gained his information as to the expedient, or whether he had gathered it from his own bitter experience, is not known; but it answered his purpose. Three cylindrical holes were built over each haunch the lowest and outermost nine feet in diameter, the next six feet, and the highest and innermost three feet. The arch, the same in width as that which fell four years before, was finished in 1755, and the beautiful "rainbow bridge" lightly spans the Taff at Newbridge to this day.

The singular inflexibility of purpose displayed by our engineer in grappling with and overcoming the difficulties encountered by him in the erection of his first bridge, became the subject of general interest throughout Wales. When it was finished and opened for public traffic, and the news spread abroad that the extraordinary arch of Pont-y-Prydd at last stood firm as the rocks on which it rested, strangers flocked from all parts to view it, and the Welsh people, as was natural, became proud of their countryman. Employment flowed in upon him, and he went on building bridge after bridge in all parts of South Wales.

Among the more important of the later works of Edwards were the large and handsome bridge over the river Usk, at the town of Usk, in Monmouthshire; one, of three arches, over the river Tame, near Swansea; another, of one arch of 95 feet span, over the same river near Morriston; a third, with an arch of 80 feet, at Pont-cer-Tame, several miles higher up; and Bettws and Llandovery Bridges, in the county of Caermarthen, the latter of 84 feet span. He also built Aberavon Bridge, in Glamorganshire, with an arch of 70 feet span; and Glasbury Bridge, of four arches, over the Wye, near Hay, in Brecknockshire, which was afterwards carried away by one of the floods so common in the district.

Edwards's strong judgment and keen observant faculties, ripened by experience, enabled him, as he grew older, to introduce many improvements in his bridges. He flattened his arches, so as to render the passage of vehicles over them more easy than in the case of Pont-y-Prydd, - the steepness on either side of which was found to be so great an obstacle, that it was afterwards found necessary to supersede its use by a more level bridge erected on modern principles. Hence his later works presented a considerable improvement in this respect upon his earlier ones: and while he continued to be equally careful in providing ample water-way under the arching, and to erect his bridges with a view to the greatest possible durability, he took increasing pains to provide a more capacious and level roadway over them, and to render them in all ways more easy and convenient for public use.

Besides his numerous bridges, Edwards continued, during the remainder of his long life, to erect smelting-houses, forges, and buildings of various kinds for purposes of manufacture. Nor did his building business exclusively occupy his time, for, in addition to his profession of building engineer, he carried on the business of a farmer until the close of his life. Not even on Sundays did he cease from his labours. The Sabbath was no day of rest for him, but his labours then were all labours of love.

In 1750 he became an ordained preacher amongst the Independents. Shortly after, he was chosen minister of the congregation to which he belonged, and he continued to hold the office for about forty years, until his death. He occasionally preached in the neighbouring meeting-houses: amongst others, in that of Mr. Rees, the father of Abraham Rees, editor of the well-known 'Encyclopedia.' This meeting-house was one of the numerous buildings erected by Edwards himself.

He always preached in Welsh, and his discourses are said to have been simple, sensible, and full of loving-kindness. His fellow-countryman Malkin * says of him, that, though a Calvinist, he was one of a very liberal description; indeed, he carried his charity so far that many persons suspected he had changed his opinions, and for that reason spoke very unhandsomely of him. As he grew older he became increasingly charitable, and tolerant of other men's views, avoiding points of doctrinal difference, but urging and enforcing that the love of God and of our neighbour is the aim and end of all religion. Holding it to be the duty of every religious society to contribute liberally of their means to the support of their ministry, he regularly took the stipulated salary which his congregation allowed to their preachers, but distributed the whole of it amongst the poorer members of his church, often adding to it largely from his own means.

This worthy engineer died at the advanced age of seventy, respected and beloved by men of all parties; and he was buried in the churchyard of his native parish of Eglwysilan, amidst the graves of his children. Three of his sons were, like their father, eminent bridge-builders: David having constructed the fine five-arched bridge over the Usk at Newport, as well as the bridges at Llandilo, Edwinsford, Pontloyrig, Bedwas, and other places. Indeed, William Edwards may be said to have fairly inaugurated the revival of the art of bridge-building in England. After his time, it was taken up by Smeaton, Rennie, and Telford, and its progress will accordingly be described in connection with the lives and works of those distinguished engineers.

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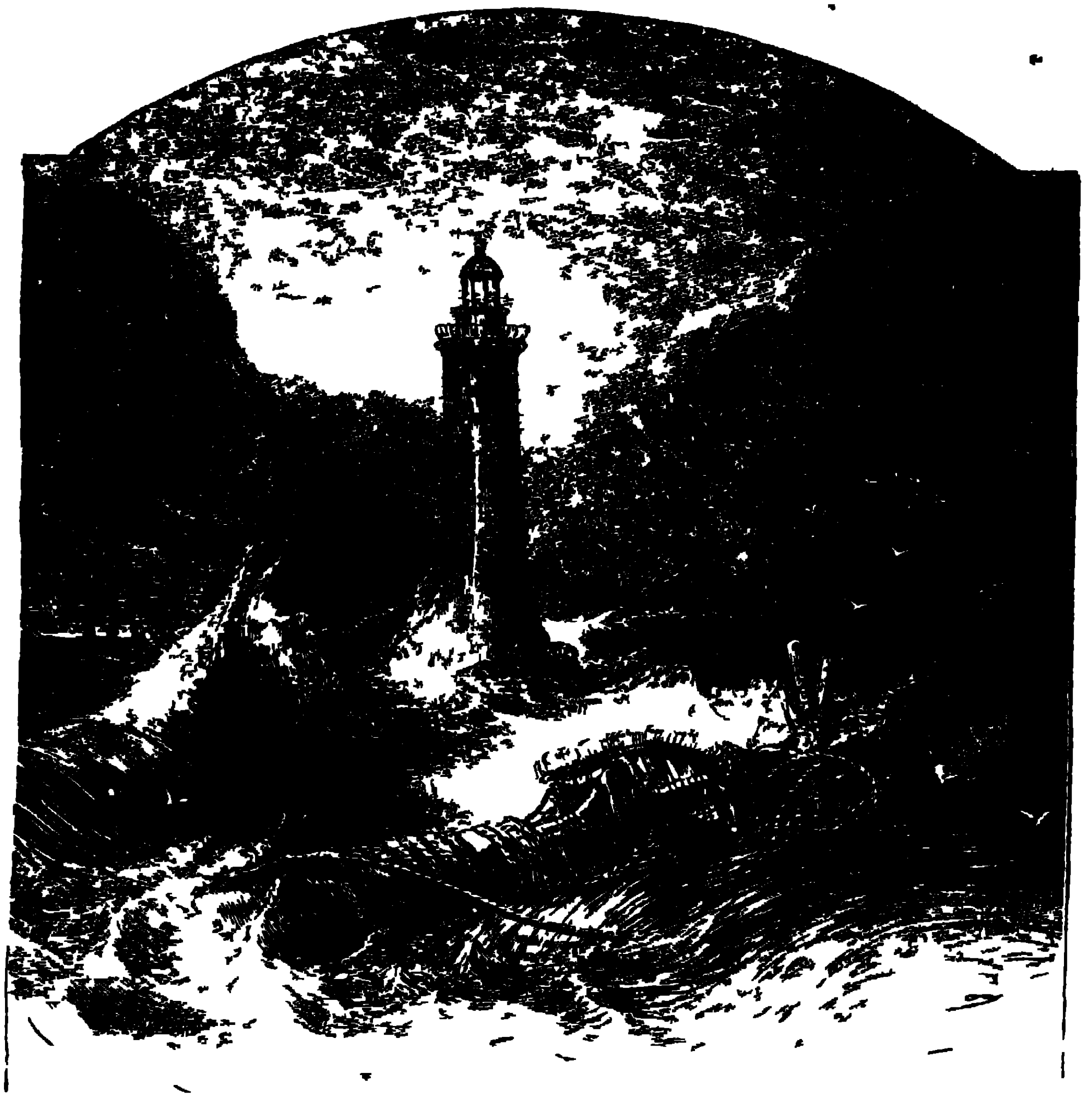
* 'The Scenery, Antiquities, and Biography of South Wales.' By Benjamin Heath Malkin, Esq., M.A. F.A.S. 1807, Vol i. p. 144.

LIFE OF JOHN SMEATON.



EDDYSTONE LIGHTHOUSE. [By Percival Skelton.]

Far in the bosom of the deep,
O'er these wild shelves my watch I keep,
A ruddy gem of changeful light
Bound in the dusky brow of night,
The seaman bids my lustre hail
And scorns to strike his timorous sail.—*Sir Walter Scott.*

LIFE OF JOHN SMEATON.

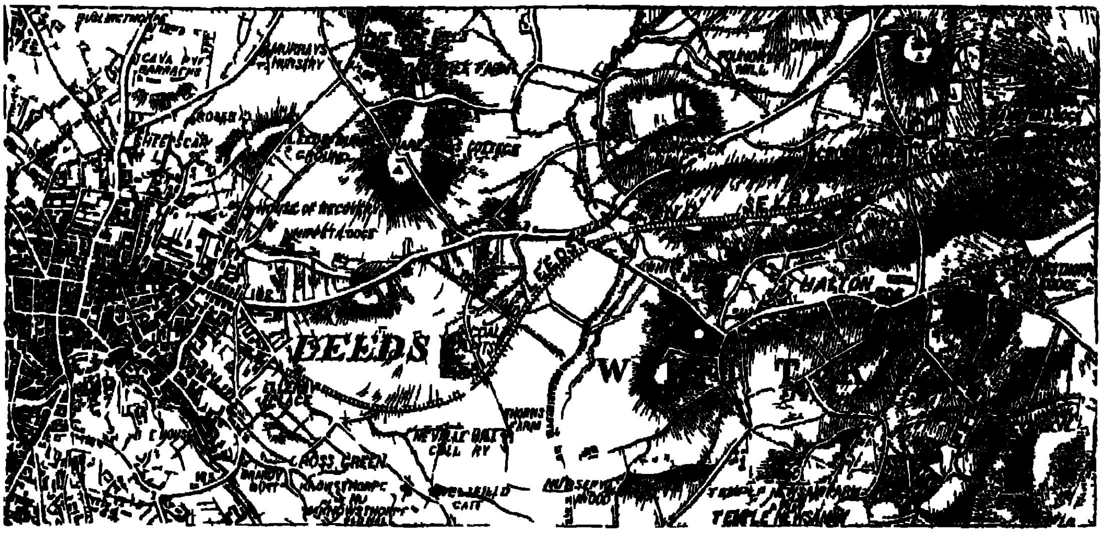
CHAPTER I.

SMEATON'S BOYHOOD AND EDUCATION.

THE engineer of the Eddystone Lighthouse was Brindley's junior by only eight years. They frequently met in consultation upon important engineering undertakings; sometimes Smeaton advising that Brindley should be called in, and Brindley, on his part, recommending Smeaton. They were, in fact, during their lifetime, the leading men in their profession; and at Brindley's death Smeaton succeeded to much of his business as consulting engineer in connection with the construction of canals and of public works generally.

Smeaton had the great advantage over Brindley of a good education and bringing up. He had not, like the Macclesfield millwright, to force his way up through the obstructions of poverty, toil, and parental neglect; but was led gently by the hand from his earliest years, and carefully trained and cultured after the best methods then known. But Smeaton, not less than Brindley, was impelled to the career on which he entered, by a like innate genius for construction, which displayed itself at a very early age; and, being permitted to follow his own bent, his force of character and strong natural ability, diligently cultivated by study and experience, eventually carried him to the very highest eminence as an engineer.

John Smeaton was born at Austhorpe Lodge, near Leeds, on the 8th of June, 1724, his father being a respectable attorney practising in that town. The house in which the future engineer was born was built by his grandfather John Smeaton, who is described on the tablet to his memory erected in the neighbouring parish church of Whitkirk, as "late of York."



Smeaton's Native District [Ordnance Survey]

Leeds was then a place of small importance, compared with what it is now. The principal streets were those still known as Briggate, leading to the bridge; Kirkgate, leading to the parish church, and Swinegate, leading to the old castle. Beyond those streets lay a wide extent of open fields. Boar Lane, now nearly the centre of the town, was a kind of airy suburb in which the principal merchants resided; and the back of the houses in the upper part of Briggate, now the main street, looked into the country,* or to "the Park," on which Park Square, Park Row, and Park Lane (now containing the new Town Hall), have since been built. There were also green fields, with pleasant footpaths, between the parish church and

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Whitaker's Thoresby, 'Loidis and Elmete,' p. 89.

the river Aire, through certain gardens, then, as now, named "The Calls," though the gardens exist no longer.

The clothing trade of the town was then so small that the cloth market was held in the open air upon the bridge, where the cloth was exposed for sale on the parapets. The homely entertainment of the clothiers at that day was a "brigend shot," consisting of a noggin of porridge and a pot of ale, followed by a twopenny trencher of meat. Down to the year 1730, the bridge was so narrow that only one cart could pass over it at a time. But the number of wheeled vehicles then in use was so small that the inconvenience was scarcely felt. The whole of the cloth was brought to market on men's and horses' backs.[*] Coals were in like manner carried from the pits on horseback, the stated weight of a "horse-pack" being eighteen stone, or equal to two hundredweight and a quarter.[†] In the rural districts of Yorkshire, manure was also carried a-field on horses' backs, and sometimes on women's backs, while the men sat at home knitting.[‡] The cloth-packs were carried by the "bell-horses," or pack-horses; and this mode of conveyance continued until towards the end of last century. Scatcherd says the pack-horses only ceased to travel about the year 1794.

The Leeds men, it seems, were not considered so "quick" as those of Bradford, then a much smaller place and comparatively of the dimensions of a village. It was long before the Leeds people provided themselves with a market for their cloth. The first was on Mill Hill, afterwards removed to the Calls; and finally, in 1757, they erected a large hall for the market in the Park, now known as the Coloured Cloth Hall. But even then the place remained comparatively rural as regards its extent and its surrounding country.

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[*] This is clear from an allusion made by Thoresby to an Act passed in 1714, regulating the manufacture of broad-cloth, by which the length was increased from four or six-and-twenty to sixty and even seventy yards, "to the great oppression," says Thoresby, "both of man and beast in carriage."

[†] Smeaton's 'Reports,' vol. iii. p. 410. Mr. Smeaton says that before the invention of rail or waggon roads at Newcastle, "all the coals that were carried down to the ships must have been conveyed on horses' backs." What was called "a bowl of coals," was reckoned a horse-load; and in Yorkshire (where the first waggon-way was laid within Smeaton's recollection) the load of coals and the "horse-pack" were readily substituted the one for the other

[‡] Brockett's 'Glossary of North Country Words.' Newcastle, 1825.

View of Leeds, early part of 1[illegible]th Century.* [From Thoresby's 'Ducatus Leodensis.']

Smeaton was greatly favoured in his home and his family. He received his first education at his mother's knees; and when not occupied with his lessons he led the life of a healthy, happy country boy. Austhorpe was then quite in the country, the only houses in the neighbourhood being those of the little hamlet of Whitkirk, with the large old mansion of Temple Newsam, surrounded by its noble park and woods, close at hand. Young Smeaton was not much given to boyish sports, and early display of a thoughtfulness beyond his years. Most children are naturally fond of building up miniature fabrics, and perhaps still more so of pulling them down. But little Smeaton seemed to have a more than ordinary love of contrivance, and that mainly for its own sake. He was never so happy as when put in possession of any cutting-tool, by which he could make his little imitations of houses, pumps, and windmills. Even while a boy in petticoats, he was continually dividing circles and squares, and the only playthings in which he seemed to take any real pleasure, were the models of things that would "work."

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* The principal buildings shown in the above view of Leeds, about the time when Smeaton was born are the Parish Church (described by Thoresby as "black, but comely"), St. John's Church, and Call Lane Chapel.

When any carpenters or masons were employed in the neighbourhood of his father's house, the inquisitive boy was sure to be amongst them, watching the men, and observing how they handled their tools. He would also bother the workpeople with questions, many of which they could not answer, nor even understand. His life-long friend, Mr. Holmes,* who knew him in his youth, has related that having one day observed some millwrights at work, he was seen shortly after, to the great alarm of his family, fixing something like a windmill on the top of his father's barn. On another occasion, when watching some workmen fixing a pump in the village, he was so lucky as to procure from them a piece of bored pipe, which he succeeded in fashioning into a working pump that actually raised water. His odd cleverness, however, does not seem to have been appreciated; and it is told of him that amongst the other boys he was known as "Fooely Smeaton;" for, though forward enough in putting questions to the workpeople, among boys of his own age he was remarkably shy, and, as they thought, stupid.

At a proper age the boy was sent to school at Leeds. The town then possessed, as it still does, the great advantage of an excellent Free Grammar School, founded by the benefactions of Catholics in early times, afterwards greatly augmented by the endowment of one John Harrison, a native of the town, about the period of the Reformation. At this school Smeaton is supposed to have received the best part of his school instruction, and it is said that his progress in geometry and arithmetic was very decided; but, as before, the chief part of his education was conducted at home, amongst his tools and his model machines. There he was incessantly busy whenever he had a spare moment.

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* An eminent clock and watchmaker in the Strand, afterwards Smeaton's partner in the Deptford Waterworks. His 'Short Narrative of the Genius, Life, and Works of the late Mr. John Smeaton, C.E., F.R.S.' published in 1793, contains the gist of nearly all the notices of Smeaton's life which have since been published; though it is but a meagre account of only a few pages in length.

Indeed, his mechanical ingenuity sometimes led him to play tricks which involved him in trouble. Thus, it happened that some mechanics came into the neighbourhood to erect a "fire-engine,"—as the steam-engine was then called - for the purpose of pumping water from the Garforth coal-mines; and Smeaton made daily visits to them for the purpose of watching their operations. Carefully observing their methods, he proceeded to make a miniature engine at home, provided with pumps and other apparatus, and he even succeeded in getting it set to work before the colliery engine was ready. He first tried its powers upon one of the fish-ponds in front of the house at Austhorpe, which he succeeded in pumping completely dry, and thereby killed all the fish in the pond, very much to the surprise as well as the annoyance of his father.

But his father seems to have been indulgent, if he was not proud of his boy, for he provided him with a workshop in an outhouse, where he hammered, filed, and chiselled, very much to his heart's content. Working on in this way, young Smeaton contrived, by the time he had reached his fifteenth year, to make a turning-lathe, on which he turned wood and ivory, and made presents of little boxes and other articles to his various friends. He also learned to work in metals, which he fused and forged himself; and by the age of eighteen, he could handle tools with the expertness of any regular smith or joiner.

"In the year 1742," says his friend, Mr. Holmes, "I spent a month at his father's house; and being intended myself for a mechanical employment, and a few years younger than he was, I could not but view his works with astonishment. He forged his iron and steel, and melted his metal. He had tools of every sort for working in wood, ivory, and metals. He had made a lathe, by which he cut a perpetual screw in brass,—a thing little known at that day, and which, I believe, was the invention of Mr. Henry Hindley, of York, with whom I served my apprenticeship. Mr. Hindley was a man of the most communicative disposition, a great lover of mechanics, and of the most fertile genius. Mr. Smeaton soon became acquainted with him, and spent many a night at Mr. Hindley's house till daylight, conversing on these subjects."

Whitkirk, near Leeds. [By E. M. Wimperis, after a Sketch by I. Sutcliffe.]

CHAPTER II.

SMEATON LEARNS THE TRADE OF MATHEMATICAL INSTRUMENT MAKER.

YOUNG SMEATON left school in his sixteenth year, and from that time he was employed in his father's office, copying legal documents, and passing through the necessary preliminary training to fit him to follow the profession of an attorney. Mr. Smeaton, having a good connection in his native town, naturally desired that his only son should succeed him. But the youth took no pleasure in Law: his heart was in his workshop with his tools. Though he mechanically travelled to the office daily, worked assiduously at his desk, and then travelled back again to Austhorpe, he every day felt more and more the irksomeness of his employment.

Partly to wean him from his mechanical pursuits at home, which often engrossed his attention half the night, and partly to give him the best legal education which it was in his power to bestow, Mr. Smeaton sent his son to London towards the end of the year 1742; and for a short time he occupied himself, in conformity with his parent's wishes, in attending the Courts in Westminster Hall. But at length he could not repress his strong desire to pursue some mechanical occupation, and in a firm but respectful memorial to his father, he fully set forth his views as to the particular calling which he wished to follow, in preference to the profession of the law.

The father's heart was touched, and probably also his good sense was influenced, by the son's earnest appeal; and he wrote back, giving his assent, though not without his strong expression of regret as to the course which his son desired to adopt. No doubt he thought that in giving up the position of a member of a learned and lucrative profession, and descending to the level of a mechanical workman, his son was performing an act of great folly; for there was no such thing then as the profession of a civil engineer. Almost the only mechanical work of importance done at that time was executed by millwrights and others, at labourers' wages, as we have already seen in the Life of Brindley. The educated classes eschewed mechanical callings, which were neither regarded as honourable nor remunerative; and that Smeaton should have felt so strongly impelled to depart from the usual course and enter upon such a line of occupation, must be attributed entirely to his innate love of construction, or, as he himself expressed it to his father, the "bent of his genius."

When he received his father's letter, the young man experienced the joy of a prisoner on hearing of his reprieve, and he lost no time in exercising his new-found liberty. He sought out for himself a philosophical instrument maker, who could give him instruction in the business he proposed to follow, and entered into his service, his father being at the expense of his maintenance. In due course of time, he was enabled to earn sufficient wages to maintain himself; but his father continued to assist him liberally on every occasion when money was required either for purposes of instruction or of business.

Young Smeaton did not live a mere workman's life. He frequented the society of educated men, and was a regular attendant of the meetings of the Royal Society. In 1750, he lodged in Great Turnstile, a passage leading from the south side of Holborn to the east side of Lincoln's Inn Fields; and shortly after, when he commenced business as mathematical instrument maker on his own account, he lodged in Furnival's Inn Court, from which his earlier papers read before the Royal Society were dated.

During the same year in which he began business, and when he was only twenty-six, he read a communication before the Royal Society, descriptive of his own and Dr. Gowin Knight's improvements in the mariner's compass. In the year following (1751) we find him engaged in a boat on the Serpentine river, performing experiments with a machine of his invention, for the purpose of measuring the way of a ship at sea. With the same object he made a voyage down the Thames, in a small sailing vessel, to several leagues beyond the Nore; and he afterwards made a short cruise in the 'Fortune' sloop of war, testing his instruments by the way.

His attention as yet seems to have been confined chiefly to the improvement of mathematical instruments used for purposes of navigation or astronomical observation. In the year 1752, however, he enlarged the range of his experiments; for we find him, in April, reading a paper before the Royal Society, descriptive of some improvements which he had contrived in the air-pump.* On the 11th of June following, he read another paper, descriptive of an improvement which he had made in ship-tackle by the construction of pulleys, by means of which one man might easily raise a ton weight; and on the 9th of November, he read a third paper, descriptive of M. De Moura's experiments on Savary's steam-engine.

In the course of the same year he was busily occupied in performing a series of experiments, on which his admirable paper was founded, read before the same Society, and for which he received their Gold Medal in 1759—entitled "An Experimental Inquiry concerning the Natural Powers of Water and Wind to turn Mills and other Machines depending on a Circular Motion." This paper was very carefully elaborated, and is justly regarded as the most masterly report that has ever been published on the subject.

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* Twenty years later, he gave this air-pump to Dr. Priestley, who found it so excellent that he brought it into public notice It enabled him to rarify air more than 400 times (Rutt, 'Life of Priestley,' i. 78 and 223.)

To accomplish all this, and at the same time to carry on his business, necessarily involved great application and industry. Indeed, Smeaton was throughout his life an indefatigable student,—bent, above all things, on self-improvement. One of his maxims was, that "the abilities of the individual are a debt due to the common stock of public happiness;" and the steadfastness with which he devoted himself to useful work, in which at the same time he found his own happiness, shows that this maxim was no mere lip-utterance on his part, but formed the very mainspring of his life. From an early period he carefully laid out his time with a view to getting the most good out of it. So much was set apart for study, so much for practical experiments, so much for business, and so much for rest and relaxation.

We infer that Smeaton could not have done much business as a philosophical instrument maker, from the considerable portion of his time which he devoted to study and experiments. Probably he already felt that, in the course of the development of English industry, a field was opening before him of a more important character than any that was likely to present itself in the mathematical instrument line. He accordingly seems early to have turned his attention to engineering, and, amongst other branches of study, he devoted several hours daily to the acquisition of French, in order that he might be able to read for himself the works on that science which were then only to be found in that and the Italian language. He had, however, a further object in studying French, which was to enable him to make a journey which he contemplated into the Low Countries, for the purpose of inspecting the great canal works of the foreign

Accordingly, in 1754, he set out for Holland, and traversed that country and Belgium, travelling mostly on foot and in treckschuyts, or canal boats, both for the sake of economy, and that he might more closely inspect the engineering works of the districts through which he passed. He there found himself in a country which had been, as it were, raked out of the very sea,—for which Nature had done so little, and skill and industry so much.

From Rotterdam he went by Delft and the Hague to Amsterdam, and as far north as Helder, narrowly inspecting the vast dykes raised round the land to secure it against the clutches of the sea, from which it had been originally won. At Amsterdam he was astonished at the amount of harbour and dock accommodation, existing at a time when London as yet possessed no conveniences of the sort.—though indeed it always had its magnificent Thames. Passing round the country by Utrecht, he proceeded to the great sea-sluices at Brill and Helvoetsluys, by means of which the inland waters discharged themselves, at the same time that the sea-waters were securely dammed out.

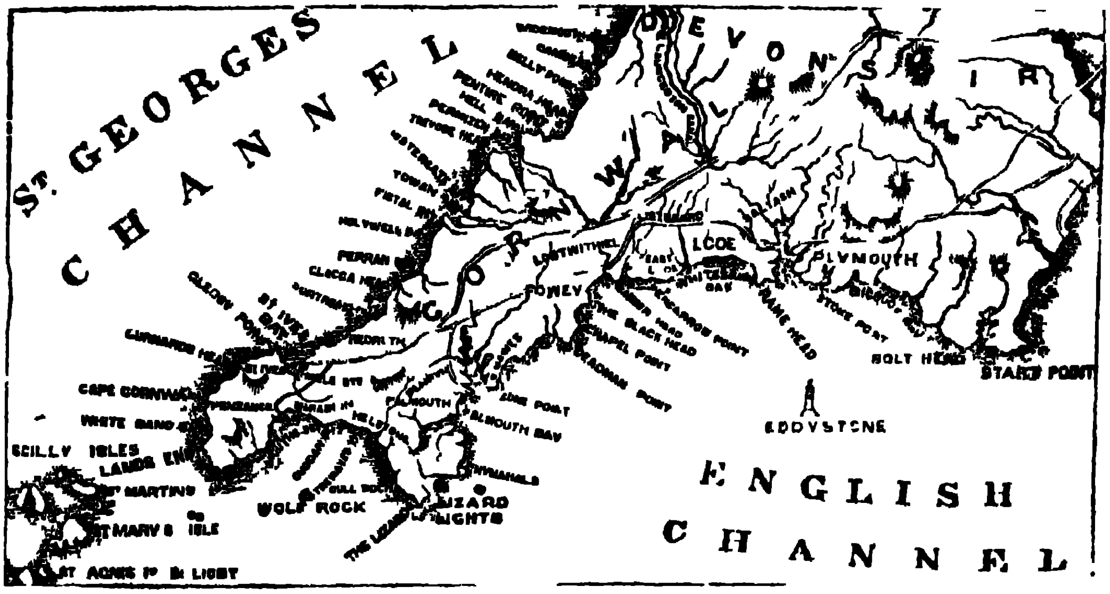
Seventeen years later, he made use of the experience which he had acquired in the course of his careful inspection of these great works, in illustrating and enforcing the recommendations contained in his elaborate report on the best means of improving Dover Harbour. He made careful memoranda during his journey, to which he was often accustomed to refer, and they proved of great practical value to him in the course of his subsequent extensive employment as a canal and harbour engineer.

Shortly after his return to England in 1755, an opportunity occurred for the exercise of that genius in construction which Smeaton had so carefully disciplined and cultivated; and it proved the turning point in his fortunes, as well as the great event of his professional life

CHAPTER III.

THE EDDYSTONE ROCK—WINSTANLEY'S AND RUDYERD'S LIGHTHOUSES.

THE Eddystone forms the crest of an extensive reef of rocks which rise up in deep water about fourteen miles S.S.W. of Plymouth Harbour. Being well out at sea, the rocks are nearly in a line with Lizard Head and Start Point; and besides being in the way of ships bound for Plymouth Sound, they lie in the very direction of vessels coasting up and down the English Channel. At low water, several long low reefs of gneiss are visible, jagged and black; but at high water they are almost completely submerged. Lying in a sloping manner towards the south-west quarter, from which the heaviest seas come,



Coast of Devon and Cornwall.

the waves in stormy weather come tumbling up the slope and break over their crest with tremendous violence. The water boils and eddies amongst the reefs, and hence the name which they have borne from the earliest times of the Eddystone Rock.

It may readily be imagined that this reef, whilst unprotected by any beacon, was a source of great danger to the mariner. Many a ship coming in from the Atlantic was dashed to pieces there, almost within sight of land and all that came ashore was only dead bodies and floating wreck. To avoid this terrible rock, the navigator was accustomed to give it as wide a berth as possible, and homeward-bound ships accordingly entered the Channel on a much more southern parallel of latitude than they now do. In his solicitude to avoid the one danger, the sailor too often ran foul of another; and hence the numerous wrecks which formerly occurred along the French coast, more particularly upon the dangerous rocks which surround the Islands of Jersey, Guernsey, and Alderney.

We have already described the rude expedients adopted in early times to light up certain of the more dangerous parts of the coast, and referred to the privilege granted to private persons who erected lighthouses, of levying tolls on passing shipping.* It was long before any private adventurer was found ready to undertake so daring an enterprise as the erection of a lighthouse on the Eddystone, where only a little crest of rock was visible at high water, scarcely capable of affording foothold for a structure of the very narrowest basis.

At length, however, in 1696, Mr. Henry Winstanley (a mercer and country gentleman), of Littlebury, in the county of Essex, obtained the necessary powers to erect a lighthouse on the Eddystone, and to levy tolls from [illegible] That gentleman seems to have possessed a curious mechanical genius, which first displayed itself in devising sundry practical jokes for the entertainment of his guests. Smeaton tells us that in one room there lay an old slipper, which, if a kick was given it, immediately raised a ghost from the floor; in another, the visitor sat down upon a chair, which suddenly threw out two arms and held him a fast prisoner; while, in the garden, if he sought the shelter of an arbour and sat down upon a particular seat, he was straightway set afloat into the middle of the adjoining canal.* These tricks must have rendered the house at Littlebury a somewhat exciting residence for the uninitiated guest. The amateur inventor exercised the same genius to a certain extent for the entertainment of the inhabitants of the metropolis, and at Hyde Park Corner he erected a variety of jets d'eau, known by the name of Winstanley's Waterworks, which he exhibited at stated times at a shilling a-head.†

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* The private lights first erected—amongst which were those on Dungeness, the Skerries (off the Isle of Anglesey), the Eddystone, Harwich, Wintertonness and Orfordness, Hunstanton Cliff, &c.—have all been purchased by the Trinity Board, some of them at very large prices. The revenue of the Skerries Light alone, previous to its purchase by the Trinity House, amounted to about 20,000*l*. a year.

This whimsicality of the man in some measure accounts for the oddity of the wooden building erected by him on the Eddystone rock; and it is matter of surprise that it should have stood the severe weather of the English Channel for several seasons. The building was begun in the year 1696, and finished in four years. It must necessarily have been a work attended with great difficulty as well as danger, as operations could only be carried on during fine weather, when the sea was comparatively smooth. The first summer was wholly spent in making twelve holes in the rock, and fastening twelve irons in

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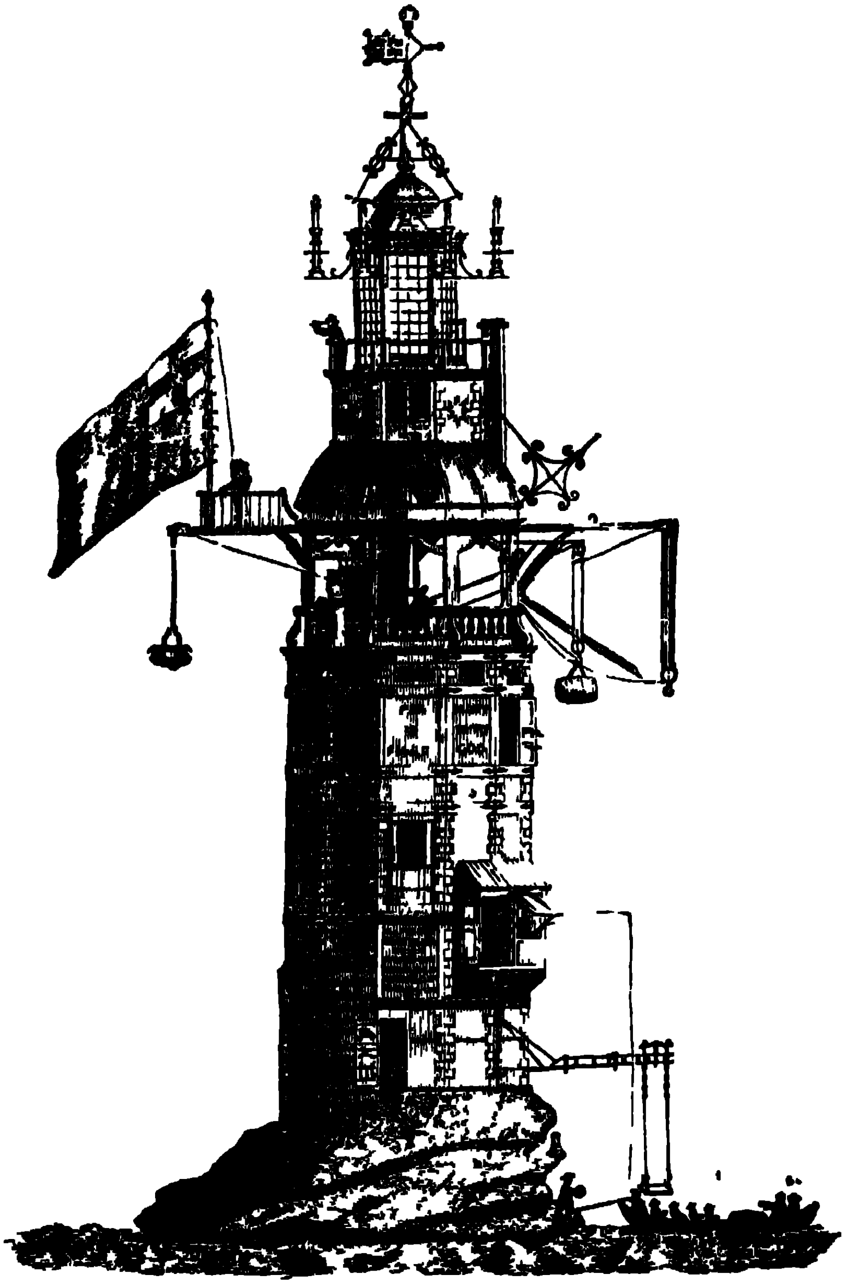
[illegible]arrative of the Building and Description of the Construction of the Eddystone Lighthouse with Stone.' By John Smeaton, Civil Engineer, F.R.S. Second Edition. London, 1813.

† They continued to be exhibited for some time after Mr Winstanley's death. See 'Tatler' for September, 1709.

them by which to hold fast the superstructure. "Even in summer," Winstanley says, "the weather would at times prove so bad, that for ten or fourteen days together the sea



Winstanley's Lighthouse

would be so raging about these rocks, caused by outwinds and the running of the ground seas coming from the main ocean, that although the weather should seem and be most calm in other places, yet here it would mount and fly more than two hundred feet, as has been so found since there was lodgment on the place, and therefore all our works were constantly buried at those times, and exposed to the mercy of the seas."

The second summer was spent in making a solid pillar, twelve feet high and fourteen feet in diameter, on which to build the lighthouse. In the third year, all the upper work was erected to the vane, which was eighty feet above the foundation. In the midsummer of that year Winstanley ventured to take up his lodging with the workmen in the lighthouse; but a storm arose, and eleven days passed before any boats could come near them. During that period the sea washed in upon Winstanley and his companions, wetting all their clothing and provisions, and carrying off many of their materials. By the time the boats could land, the party were reduced almost to their last crust; but happily, the building stood, apparently firm. Finally, the light was exhibited on the summit of the building on the 14th of November, 1698.

The fourth year was occupied in strengthening the building round the foundations, making all solid nearly to a height of twenty feet, and also in raising the upper part of the lighthouse forty feet, to keep it well out of the wash of the sea. This timber erection, when finished, somewhat resembled a Chinese pagoda, with open galleries and numerous fantastic projections. The main gallery under the light was so wide and open, that an old gentleman who remembered both Winstanley and his lighthouse, afterwards told Smeaton, that it was "possible for a six-oared boat to be lifted up on a wave, and driven clear through the open gallery into the sea on the other side." In the perspective print of the lighthouse, published by the architect after its erection, he complacently represented himself as fishing out of the kitchen-window!

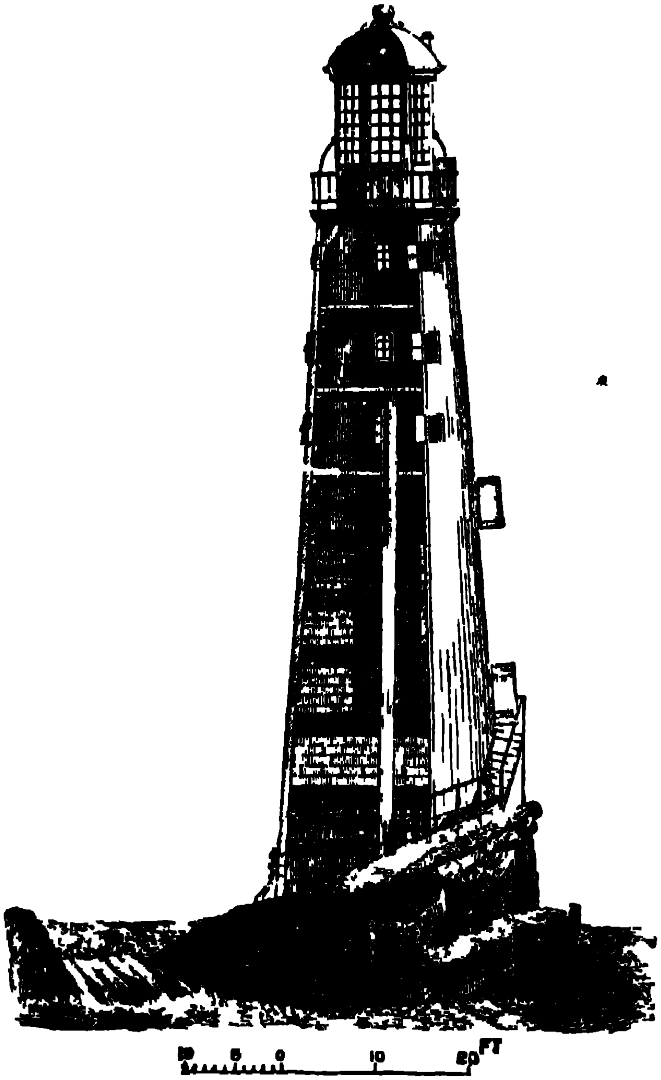
When Winstanley had brought his work to completion, he is said to have expressed himself so satisfied as to its strength, that he only wished he might be there in the fiercest storm that ever blew. In this wish he was not disappointed, though the result was entirely the reverse of the builder's anticipations. In November, 1703, Winstanley went off to the lighthouse to superintend some repairs which had become necessary, and he was still in the place with the lightkeepers, when, on the night of the 26th, a storm of unparalleled fury burst along the coast. As day broke on the morning of the 27th, people on shore anxiously looked in the direction of the rock to see if Winstanley's structure had withstood the fury of the gale; but not a vestige of it remained. The lighthouse and its builder had been swept completely away.

The building had, in fact, been deficient in every element of stability, and its form was such as to render it peculiarly liable to damage from the violence both of wind and water. "Nevertheless," as Smeaton generously observes, "it was no small degree of heroic merit in Winstanley to undertake a piece of work which had before been deemed impracticable, and, by the success which attended his endeavours, to show mankind that the erection of such a building was not in itself a thing of that kind." He may, indeed, be said to have paved the way for the more successful enterprise of Smeaton himself; and his failure was not without its influence in inducing that great mechanic to exercise the care which he did, in devising a structure that should withstand the most violent force of the sea on the south coast. Shortly after Winstanley's lighthouse had been swept away, the 'Winchelsea,' a richly-laden homeward-bound Virginiaman, was wrecked on the Eddystone rock, and almost every soul on board perished; so that the erection of a lighthouse upon the dangerous reef remained as much a necessity as ever.

A new architect was not long in making his appearance. He did not, however, come from the class of architects, or builders, or even of mechanics: and, as for the class of engineers, it had not yet sprung into existence. The projector of the next lighthouse for the Eddystone was again a London mercer, who kept a silk-shop on Ludgate Hill. John Rudyerd—for such was his name—was, however, a man of unquestionable genius, and possessed of much force of character. He was the son of a Cornish labourer whom nobody would employ,—his character was so bad; and the rest of the family were no better, being looked upon in their neighbourhood as "a worthless set of ragged beggars." John seems to have been the one sound chick in the whole brood. He had a naturally clear head and honest heart, and succeeded in withstanding the bad example of his family. When his brothers went out a-pilfering, he refused to accompany them, and hence they regarded him as sullen and obstinate. They ill-used him, and he ran away. Fortunately he succeeded in getting into the service of a gentleman at Plymouth, who saw something promising in his appearance. The boy conducted himself so well in the capacity of a servant, that he was allowed to learn reading, writing, and accounts; and he proved so quick and intelligent, that his kind master eventually placed him in a situation where his talents could have better scope for exercise than in his service, and he succeeded in thus laying the foundation of the young man's future success in life.

We are not informed of the steps by which Rudyerd worked his way upward, until we find him called from his silk-mercer's shop to undertake the rebuilding of the Eddystone Lighthouse. But it is probable that by this time he had become known for his mechanical skill in design, if not in construction, as well as for his thoroughly practical and reliable character as a man of business; and that for these reasons, amongst others, he was selected to conduct this difficult and responsible undertaking.

After the lapse of about three years from the destruction of Winstanley's fabric, the Brethren of the Trinity, in 1706, obtained an Act of Parliament enabling them to rebuild the lighthouse, with power to grant a lease to the undertaker. It was taken by one Captain Lovet for a period of ninety-nine years, and he it was that found out and employed Rudyerd. His design of the new structure was simple but masterly. He selected the form that offered the least possible resistance to the force of the winds and the waves, avoiding the open galleries and projections of his predecessor. Instead of a polygon he chose a cone for the outline of his building, and he carried up the elevation in that form. In the practical execution of the work he was assisted by two shipwrights from the King's yard at Woolwich, who worked with him during the whole time that he was occupied in the erection.



Rudyerd's Lighthouse.

The main defect of the lighthouse consisted in the faultiness of the material of which it was built; for, like Winstanley's, it was of wood. The means employed to fix the work to its foundation proved quite efficient; dove-tailed holes were cut out of the rock, into which strong iron bolts or branches were keyed,* and the interstices were afterwards filled with molten pewter. To these branches were firmly fixed a crown of squared oak balks, and across these a set of shorter balks, and so on, till a basement of solid wood was raised, the whole being firmly fitted and tied together with tre-nails and screw-bolts. At the same time, to increase the weight and vertical pressure of the building, and thereby present a greater resistance to any disturbing external force, Rudyerd introduced numerous courses of Cornish moorstone, as well jointed as possible, and cramped with iron. It is not necessary to follow the details of the construction further than to state, that outside the solid timber and stone courses strong upright timbers were fixed, and carried up as the work proceeded, binding the whole firmly together.

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* Mr. Smeaton says that the instrument now called the Lewis

Within these upright timbers the rooms of the lighthouse were formed, the floor of the lowest, the storeroom, being situated twenty-seven feet above the highest side of the rock. The upper part of the building comprehended four rooms, one above another, chiefly formed by the upright outside timbers, scarfed - that is, the ends overlapping, and firmly fastened together. The whole building was, indeed, an admirable piece of ship-carpentry, excepting only the moorstone, which was merely introduced, as it were, by way of ballast. The outer timbers were tightly caulked with oakum, like a ship, and the whole was payed over with pitch. Upon the roof of the main column Rudyerd fixed his lantern, which was lit by candles, seventy feet above the highest side of the foundation, which was of a sloping form. From its lowest side to the summit of

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though an invention of old date, was for the first time made use of by Rudyerd in fixing his iron branches firmly to the rock. "Mr. Rudyerd's method," he says, "of keying and securing, must be considered as a material accession to the practical part of engineering, as it furnishes us with a secure method of fixing ring-bolts and eye-bolt stanchions, &c., not only in rocks of any known hardness, but into piers, moles, &c., that have been already constructed, for the safe mooring of ships, or fixing additional works whether of stone or wood." (Smeaton's 'Narrative,' p. 22.)

the ball fixed on the top of the building was ninety-two feet, the timber-column resting on a base of twenty-three feet four inches. "The whole building," says Smeaton, "consisted of a simple figure, being an elegant frustum of a cone, unbroken by any projecting ornament, or anything whereon the violence of the storms could lay hold." The structure was completely finished in 1709, though the light was exhibited in the lantern as early as the 28th of July, 1706.*

That the building erected by Rudyerd was on the whole well adapted for the purpose for which it was intended, was proved by the fact that it served as a lighthouse for ships navigating the English Channel, and withstood the fierce storms which rage along that part of the coast, for a period of nearly fifty years. The lighthouse was at first attended by only two men, as their duty required no more. During the night they kept watch by turns for four hours alternately, snuffing and renewing the candles. It happened, however, that one of the keepers took ill and died, and only one man remained to do the work. He hoisted the flag as a signal to those on land to come off to his assistance; but the sea was running so high at the time, that no boat could live in the vicinity of the rock; and the rough weather lasted for nearly a month.

What was the surviving man to do with the dead body of his comrade? The thought struck him that if he threw it into the sea, he might be charged with murder. He determined, therefore, to keep the corpse in the lighthouse until a boat could come off from the shore One may imagine the horrors endured by the surviving lightkeeper during that long, dismal month. At last the boat came off, but the weather was still so rough that a landing was only effected with the greatest difficulty. By this time the effluvia rising from the corpse was overpowering; it filled the apartments of the lighthouse, and it was all that the men could do to get the body disposed of by throwing it into the sea. The circumstance afterwards induced the proprietors to employ a third man to supply the place of a disabled or dead keeper.*

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* An anecdote is told of a circumstance which occurred during its erection, so creditable to Louis XIV., then King of France, that we repeat it here. There being war at the time between France and England, a French privateer took the opportunity of one day seizing the men employed upon the rock, and carrying them off prisoners to France. But the capture coming to the ears of the King, he immediately ordered that the prisoners should be released and sent back to their work with presents, declaring, that, though he was at war with England, he was not at war with mankind; and, moreover, that the Eddystone Lighthouse was so situated as to be of equal service to all nations having occasion to navigate the channel that divided France from England. (Smeaton's 'Narrative,' p. 28.)

The chief defect of Rudyerd's building, as we have already observed, consisted not in its form, but in the material of which it was composed. It was combustible, and yet it could only be made useful as a lighthouse by the constant employment of fire in some shape. Though the heat of the candles used in the lantern may not have been very great, still it was sufficient to produce great dryness and inflammability in the timbers lining the roof, and these being covered with a crust of soot, must have proved a source of constant danger. The immediate cause of the accident by which the lighthouse was destroyed, was never ascertained. All that is known is, that about two o'clock in the morning of the 2nd December, 1755, the lightkeeper on duty, going into the lantern to snuff the candles, found it full of smoke.

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* The employment of a lighthouse keeper was very healthy There was always a large number of candidates for any vacant office, probably of the same class to which pike-keepers belong. They must have been naturally morose, and, perhaps slightly misanthropic, for Mr. Smeaton relates that, some visitors having once landed at the rock, one of them observed to the light-keeper how comfortably they might live there in a state of retirement :—"Yes," replied the man, "very comfortably if we could have the use of our tongues; but it is now a full month since my partner and I have spoken a word to each other!"

The lighthouse was on fire! In a few minutes the wooden fabric was in a blaze. Water could not be brought up the tower by the men in sufficient quantities to be thrown with any effect upon the flames raging above their heads: the molten lead fell down upon the lightkeepers, into their very mouths,* and they fled from room to room, the fire following them down towards the basement on the rock. From Cawsand and Rame Head the unusual glare of light proceeding from the Eddystone was seen in the early morning, and fishing-boats with men went off to the rock, though a fresh east wind was blowing. By the time they reached it, the lightkeepers had not only been driven from all the rooms, but, to protect themselves from the molten lead and red-hot bolts and falling timbers, they had been compelled to take shelter under a ledge of the rock on its eastern side. The surf was too high to enable the boats to effect a landing; but the men themselves, becoming conscious of their perilous situation, adopted the only means of escape which now remained. By great efforts, a small boat had been got near enough to throw a coil of rope upon a projection of the rock, and the men had sufficient energy to lay hold of it, and one by one to fasten it round their bodies, and jump into the sea. They were thus towed on board the boats, and were shortly after landed at Plymouth, more dead than alive.

And thus also was Rudyerd's timber lighthouse completely destroyed. As the necessity, however, for protecting the navigation of the Channel by a light on the Eddystone was now greater than ever, in consequence of the increasing foreign as well as coasting trade of the kingdom, it was immediately determined by the proprietors to take the necessary steps for rebuilding it; and it was at this juncture that Smeaton was applied to. As on the two previous occasions, when a mercer and country gentleman, and then a London silk-mercer had been called upon to undertake this difficult work, the person now applied to was not a builder, nor an architect, nor an engineer, but a mathematical instrument maker. Mr. Smeaton had, however, by this time gained for himself so general an estimation amongst scientific men as a painstaking observer, an able mechanic, and one who would patiently master, and, if possible, overcome any amount of difficulties, that he was at once pointed out as the person of all others who was the most capable of satisfactorily rebuilding this important beacon on the south-western coast.

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* It appears that a post-mortem examination of one of the lightkeepers (who died from injuries received during the fire) took place some thirteen days after its occurrence, and a flat oval piece of lead, some seven ounces in weight, was taken out of his stomach, having proved the cause of his death.

CHAPTER IV.

SMEATON'S LIGHTHOUSE ON THE EDDYSTONE.

CAPTAIN LOVET, the lessee of the lighthouse, having died in 1715, his property was sold, and Mr. Robert Weston, in company with two others, became the purchasers of the lease. On the destruction of Rudyerd's timber building, Mr. Weston applied to the Earl of Macclesfield, President of the Royal Society, for his advice under the circumstances, and requested him to point out an architect capable of undertaking the reconstruction of the lighthouse in an efficient manner. Mr. Smeaton's account of the reply made by the Earl to Mr. Weston is so characteristic of him, that we quote his own words.

Lord Macclesfield replied "that there was one of their own body whom he could venture to recommend to the business; yet that the most material part of what he knew of him was, his having within the compass of the last seven years recommended himself to the Society by the communication of several mechanical inventions and improvements; and that though he had at first made it his business to execute things in the instrument way (without having ever been bred to the trade), yet on account of the merit of his performances he had been chosen a member of the Society; and that for about three years past, having found the business of a philosophical instrument maker not likely to afford an adequate recompense, he had wholly applied himself to such branches of mechanics as he (Mr. Weston) had appeared to want; that he was then somewhere in Scotland, or in the north of England, doing business in that line; that what he had to say of him further was, his never having known him undertake anything but what he completed it to the satisfaction of those who employed him, and that Mr Weston might rely upon it, when the business was stated to him, he would not undertake it unless he clearly saw himself capable of performing it."*

This description seems to have been enough for Mr. Weston, who immediately addressed Mr. Smeaton on the subject. News then travelled so slowly, and the particulars which had got abroad relating to the accident at the Eddystone were so meagre, that Smeaton did not know that the lighthouse had been totally destroyed. When he at length received Mr. Weston's letter, more than a month after the accident, he fancied that it was only the repair of some of the upper works that was required of him, and he replied that he had engagements on hand that he could not leave upon an uncertainty. The answer he received was, that the former building was totally destroyed that the lighthouse must be rebuilt and the letter concluded with the words, "thou art the man to do it."

Smeaton then returned to town and proceeded to consider the matter. The subject was wholly new to him; but he determined to investigate it thoroughly, and he lost no time in doing so. One of the earliest conclusions he arrived at was, that stone was the proper material with which to rebuild the lighthouse, though the superiority of timber was strongly urged upon him. The popular impression, which also prevailed amongst the Brethren of the Trinity House, was, that "nothing but wood could possibly stand on the Eddystone;" and many were the predictions uttered as to the inevitable failure of a structure composed of any other material. The first thing which our engineer did was to examine carefully the plans and models of the two former lighthouses; by which he sought to ascertain their defects, with a view to avoiding them in the new erection.

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* Smeaton's 'Narrative,' &c., p 38

In the course of this inquiry, he became more and more convinced that the great defect of the late building had been its want of Weight, through which it had rocked about in heavy storms, and would probably have been washed away before long if it had not been burnt; and he came to the conclusion, that if the lighthouse was to be contrived so as not to give way to the sea, it must be made so strong as that the sea must be compelled to give way to the building. He also had regard to durability as an important point in its re-erection. To quote his own words: "In contemplating the use and benefit of such a structure as this, my ideas of what its duration and continued existence ought to be, were not confined within the boundary of one Age or two, but extended themselves to look towards a possible Perpetuity."

Thus, before Smeaton had proceeded very far, he had come to the firm conviction that the new lighthouse must be built of Stone. Nevertheless, he resolved to preserve the conical form of Rudyerd's building, but to enlarge considerably the diameter of the foundation, and thus increase the stability of the whole superstructure. The idea of the bole of a large spreading oak-tree presented itself to his mind as the natural model of a column, presenting probably the greatest possible strength.

Another point which he long and carefully studied, was the best mode of bonding the blocks of stone to the rock and to each other, in such a way as that not only every individual piece, but the whole fabric, should be rendered proof against external force. Binding the blocks together by iron cramps was considered, but dismissed as insufficient, as well as impracticable. Then the process of dovetailing occurred to him—a practice then generally applied to carpentry, though scarcely as yet known in masonry. Still more suitable for his purpose was the method which he had observed adopted in fixing the kerbs along the London footpaths, by which the long pieces or stretchers were retained between the two headers or bond-pieces, whose heads being cut dovetail-wise, adapted themselves to and bound in the stretchers; and the tye being as good at the bottom as at the top, this arrangement, he conceived, was the very best that could be devised for his purpose.

From these beginnings he was readily led to think that if the blocks themselves, both inside and out, were all formed into large dovetails, they might be arranged so as mutually to lock themselves together, being first engrafted into the rock; and in the round and entire courses, along the top of the rock, they might all proceed from and be locked into one large centre stone. By thus rooting the foundations into the rock, and also binding every stone by a similar dovetailing process to every other stone in each course, upon which the sea could only act edgeways, he conceived that he would be enabled to erect a building of a strength sufficient to resist the strongest force of winds and waves that was likely to be brought against it.

Having thus thought out the subject, and deliberately matured his views—carefully studying, amongst other works, 'Wren's Parentalia' and Price's account of the building of Salisbury Cathedral—he proceeded to design a lighthouse on the principles we have thus summarily described; and, with a few modifications rendered necessary by the situation and the various circumstances which presented themselves in the course of the work, he proceeded to carry his design into effect in the building of the third Eddystone Lighthouse.

All this had been done before Mr. Smeaton had even paid a visit to the site on which the lighthouse was to be built. The difficulty of reaching the place was great, and time was precious. Besides, he thought it best to prepare himself for his first visit by completing his thorough preliminary investigation of the whole case. It was not until the end of March, 1756, that he set out from London to Plymouth for the purpose of making his first inspection of the rock. He was no less than six days in performing the journey, of which he says, "I had nothing to regret but the loss of time that I suffered, which was occasioned chiefly by the badness of the roads."

At Plymouth he met Josias Jessop, to whom he had been referred for information as to the previous lighthouse. Mr. Jessop was then a foreman of shipwrights, called a quarter-man, in Plymouth Dock, and was a person of much modesty, integrity, as well as of singular ingenuity in mechanical matters.* Smeaton also found him to be a competent draughtsman and an excellent modeller, and he cheerfully acknowledged the great assistance which he obtained from him during the progress of the work. Smeaton showed Jessop the plan of the stone building which he had already made. The foreman expressed his great surprise on first looking at it, having made up his mind that the lighthouse could only be reconstructed of wood. But he readily admitted the superiority of a stone structure, if it could only be made to stand in so very exposed and dangerous a situation.

Mr. Smeaton was anxious to go off to the rock at once; but the wind had been blowing fresh for several days, and there was so heavy a sea in the Channel, that it was not until the 2nd of April that he could set sail. On reaching the Eddystone, the sea was breaking upon the landing-place with such violence, that it was impossible to land. All that Smeaton could do was to view the cone of bare rock – the mere crest of the mountain whose base was laid so far down in the sea-deeps beneath—over which the waves were lashing, and to form a more adequate idea of the very narrow as well as turbulent site on which he was expected to erect his building.

Three days later he made a second voyage, and rejoiced on this occasion to be able to set his foot on the

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* His son, William Jessop, the engineer, became a pupil of Smeaton's, and afterwards rose to great eminence in the profession.

[illegible] upon the Eddystone. He stayed there for more [illegible] hours, and thoroughly examined the rock, being [illegible] compelled to leave it by the roughness of the sea, which began to break over it as the tide rose. The only [illegible] that he could find of the two former lighthouses [illegible] the iron branches fixed by Rudyerd, and numerous [illegible] of those fixed by Winstanley.

[illegible] a third attempt to make the rock, Smeaton was foiled by the wind, which compelled him to re-land without [illegible] having got within sight of it.

After five more days—during which the engineer was occupied in looking out a proper site for a work-yard,* [illegible] examining the granite in the neighbourhood for the purposes of the building—he made a fourth voyage, and although the vessel reached the rock, the wind was blowing so fresh and the breakers were so wild, that it was again found impossible to land. He could only direct the boat to lie off and on, for the purpose of watching the breaking of the sea and its action upon the reef.

A fifth trial, made after the lapse of a week, proved no more successful. After rowing about all day with the wind ahead, the party found themselves at night about four miles from the Eddystone, near which they anchored until morning, but wind and rain coming on they were forced to return to harbour without accomplishing their object. The sixth attempt was successful, and on the 22nd of April, after the lapse of seventeen days, Smeaton was able to effect his second landing at low water. After a further inspection the party retreated to their sloop, which lay off until the tide had fallen, when Smeaton again landed, and the night being perfectly still [illegible] "I went on with my business till nine in the evening, having worked an hour by candle-light."

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* [illegible] work-yard eventually fixed [illegible] was in a field adjacent to [illegible] situated about midway between Plymouth and Devonport, behind Drake's Island.

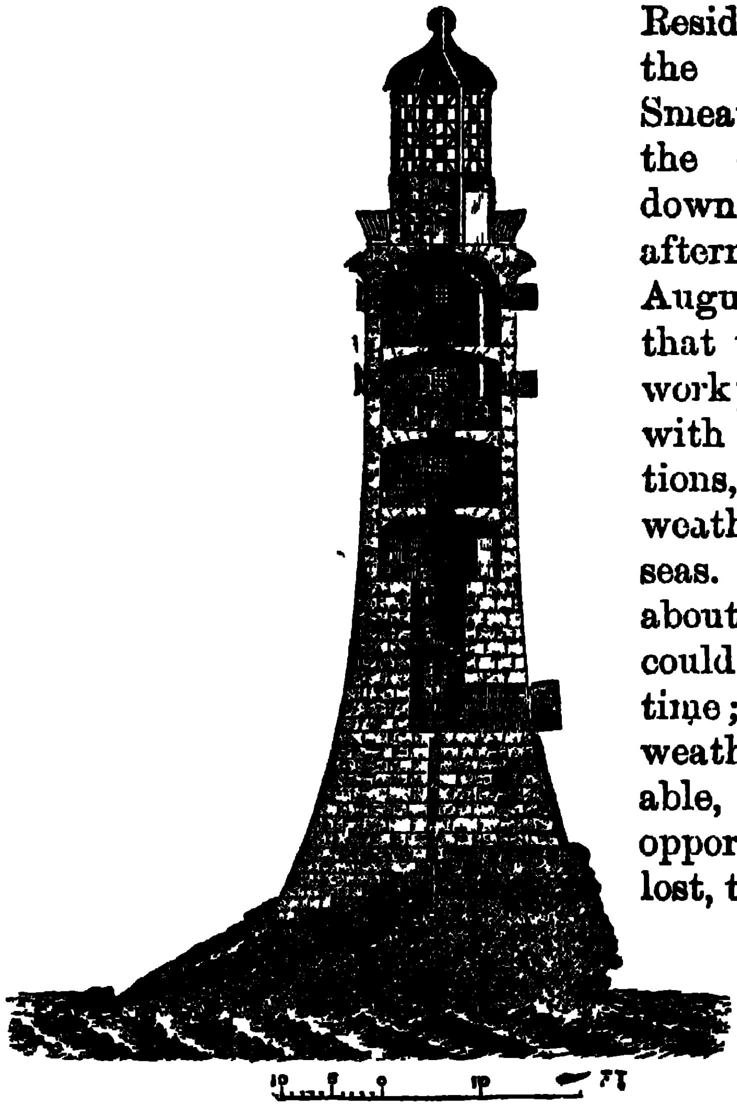
On the 23rd he again landed and pursued his operations; but this time he was interrupted by the ground swell, which sent the waves high upon the reef; and, the wind rising, the sloop was forced to put back to Plymouth. Mr. Smeaton had, however, during these visits, secured some fifteen hours' occupation on the rock, and taken dimensions of all its parts, to enable him to construct an accurate model of the foundation of the proposed building. He succeeded in obtaining such measurements as he thought would enable him to carry out his intention; but to correct the drawing, which he made to a scale, he determined upon attempting a seventh and final voyage of inspection on the 28th of April. But again the sea was found so turbulent, that a landing was impossible.

Another fortnight passed, the weather still continuing unfavourable; but meanwhile the engineer had been maturing his design, and making all requisite preliminary arrangements to proceed with the work. Among the other facilities required for carrying on the operations, was the provision of an improved landing-place, which he regarded as of essential importance. He also drew up a careful code of regulations for the guidance and government of the artificers and others who were to be employed in constructing the lighthouse. Having done all this, he arranged to proceed to London, but not until he had paid three more visits to the rock for the purpose of correcting his measurements,—in one of which he got thoroughly drenched by the spray.

On his return to town, Mr. Smeaton made his report to the proprietors, and was fully authorised by them to carry out the design which he had now matured. He accordingly proceeded to make a complete model of the lighthouse, as he intended it to be built. He thus states the reasons which prevailed with him in undertaking the construction of this model with his own hands: "Those who are not in the practice of handling mechanical tools themselves, but are under the necessity of applying to the manual operations of others, will undoubtedly conclude that I would have saved much time by employing the hands of others in this matter; and on the idea of the design being already fixed, and fully and accurately as well as distinctly made out—that is, supposing the thing done that was wanted to be done—it certainly would have been so; and had I wanted a duplicate of any part, or of the whole, when done, I should certainly have had recourse to the hands of others. But such as are in the use of handling tools for the purpose of contrivance and invention, will clearly see that, provided I could work with as much facility and despatch as those I might happen to meet with and employ, I should save all the time and difficulty, and often the vexation, mistakes, and disappointments that arise from a communication of one's own ideas to others; and that when steps of invention are to follow one another in succession and dependence on what preceded, under such circumstances it is not eligible to make use of the hands of others."

His expertness in handling tools now proved of the greatest use to him. As every course of stones in it involved fresh adaptations and the invention of new forms to give the requisite firmness and stability to the whole, it is obvious that he secured greater accuracy by executing the work with his own hands, than if he had entrusted it to any model-maker to carry out after given dimensions and drawings, however accurately they might have been laid down upon paper. After more than two months' close work, the model was ready, when it was submitted to a meeting of the proprietors and unanimously approved; as it also was by the Lords of the Admiralty, before whom it was afterwards laid. The engineer then set out for Plymouth to enter upon the necessary arrangements for preparing the foundations,—arranging with Mr. Roper, a Dorchester, on his way, for a supply of Portland stone, of which it was finally determined that the lighthouse should be built.

Artificers and foremen were appointed, working companies arranged, vessels provided for the transport of men and materials, work-yards hired and prepared. Mr. Jessop was appointed the general assistant, or as it is now termed, the Resident Engineer of the building. Mr. Smeaton himself fixed the centre and laid down the lines on the afternoon of the [illegible] August, 1756, and from that time forward the work proceeded, though with many interruptions, caused by bad weather and heavy seas. At most, only about six hours' labour could be done at a time; and when the weather was favourable, in order that no opportunity should be lost, the men proceeded by torchlight.



Section of Smeaton's Lighthouse

The principal object of the work done during the first season was to get the dovetail recesses cut out of the rock for the reception of the foundation-stones. To facilitate this process, and avoid the delay and loss of time involved by frequent voyages between the Eddystone and the shore, the 'Neptune' buss was employed as a store-vessel, and rode at anchor, at a convenient distance from the rock in about [illegible] fathoms water. But, as the season advanced, it [illegible] more and more difficult to carry on the operations. [illegible] days together the men could not land, and, even [illegible] had been able to land, they must have been washed [illegible] rock unless lashed to it. At such times the provisions in the 'Neptune' occasionally ran short, no boat [illegible] able to come off from Plymouth in consequence of [illegible] roughness of the weather. Towards the end of [illegible], the yawl riding at the stern of the buss broke [illegible] by stress of weather, and was thus lost. Mr Smeaton [illegible] most anxious, however, to finish the boring of the [illegible]ion-holes during that season, so as to commence [illegible] in the lower courses at the beginning of the next. [illegible] men, therefore, still persevered when the weather permitted, though sometimes they were only able to labour for two hours out of the twenty-four. About the end of November, the whole of the requisite cutting in the rock had been accomplished without accident, and the party prepared to return to the yard on shore, and proceed with the dressing of the stones for the work of the ensuing year.

The voyage of the buss to port, however, proved a very dangerous one, and the engineer and his men narrowly escaped shipwreck. Not being able, in consequence of the gale that was blowing, to make Plymouth Harbour, the 'Neptune' was steered for Fowey, on the coast of Cornwall. The wind rose higher and higher, until it blew quite a storm; and in the night, Smeaton, hearing a sudden [illegible] and clamour amongst the crew overhead, ran upon deck in his shirt to ascertain the cause. It was raining hard, and quite a hurricane was raging. 'It being very [illegible] he says, "the first thing I saw was the horrible [illegible]ance of breakers almost surrounding us, John [illegible], one of the seamen, crying out, 'For God's sake, [illegible] hard at that rope if you mean to save your lives!'" [illegible] immediately laid hold of the rope, at which he himself [illegible]ing as well as the other seamen, though he was also managing the helm. I not only hauled with all my strength, but called to and encouraged the workmen to do the same thing."

The sea was now heard breaking with tremendous violence upon the rocks. In this situation, the jibsail was blown to pieces, and, to save the mainsail, it was lowered, when fortunately the vessel obeyed the helm, and she rounded off. The night was so dark that nothing of the land could be seen, and the sailors did not know at what part of the coast they were; and in this uncertainty the vessel's head was put round to sea again, the waves occasionally breaking quite over her. At daybreak they found themselves out of sight of land, and the vessel driving towards the Bay of Biscay. Wearing ship, they stood once more for the coast, and before night they sighted the Land's End, but could not then make the shore. Another night and day passed, and, a vessel coming within sight, signals of distress were exhibited, and from her the 'Neptune' learned in what direction to steer for the Scilly Islands. The wind coming round, however, they bore up for the Land's End again, passed the Lizard, then Deadman's Point, then Rame Head, and finally, after having been blown about at sea for four days, they came to an anchor in Plymouth Sound, greatly to the joy of their friends, who had begun to despair of their reappearance.

The winter on shore was fully occupied in dressing stones for the next summer's work. Mr. Smeaton himself laid out all the lines on the workroom floor,* in order to insure the greatest possible accuracy in size and fitting. Nearly four hundred and fifty tons of stone were thus dressed by the time the weather was sufficiently favourable for the commencement of the building. At the same time he bestowed great pains upon experiments, which he himself conducted, for the purpose of determining the best kind of cement to be used in laying the courses of the lighthouse, and eventually fixed upon equal quantities of the lime called *blue lias* and that called *terra puzzolano*, a sufficient supply of which he was fortunate enough to procure from a merchant at Plymouth, who had imported it on adventure, and was willing to sell it cheap. It was also settled to use the finest grout for the intervals between the upright or side joints of the dovetailed part of the work.

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* Smeaton had considerable difficulty in finding a room with a floor sufficiently large on which to fit all the moulds together in the order in which they were to be permanently fixed. The engineer applied to the Mayor of Plymouth for the use of the Guildhall for the purpose, but he was refused on the pretence that the chalk-lines would spoil the floor. He was also refused the use of the Assembly-rooms for some similar reason. But at length, by taking down a partition in the coopers' workshops, he was eventually enabled to effect his purpose, without exposing himself to further refusals from the local magnates.

During the early spring, Smeaton made several visits of inspection to the quarries where the rough stones were being prepared, in order to satisfy himself as to the progress of the work. On one of such occasions a severe storm of thunder and lightning occurred at Lostwithiel, by which the church spire was shattered; and this turned his attention to the best mode of protecting his lighthouse against a similar accident. In the mean time he transmitted an account of the storm and the effects of the lightning on Lostwithiel Church to the Royal Society, amongst whose papers it stands recorded.* Dr. Franklin had shortly before published his mode of protecting lofty buildings by means of conductors, and Smeaton eventually determined, for the security of his lighthouse, to adopt his plan.

The building on the rock was fairly begun in the summer of 1757, sheers having been erected and the first stone, of two and a quarter tons weight, having been landed and securely set in its place on the morning of Sunday the 12th of June. By the evening of the following day the first course of four stones was laid.*

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* 'Philosophical Transactions,' l. 198.

The work then proceeded from time to time, as the weather permitted; and the second course, of thirteen pieces, was completed by the 30th of the same month. The workmen were occasionally interrupted by ground-swells and heavy seas, which kept them off the rock for days together. At length, on the sixth course being laid, it was found that the building had been raised above the average wash of the sea, and the progress made after that time was much more rapid. From thence the rest of the structure was raised in entire regular courses.

The manner in which the stones were prepared in the yard, arranged in courses, and brought off in the vessels, so that they could be landed in their proper order and fixed in their proper places, was simple and effective. When the separate pieces of which a course was to consist were hewn, they were all brought together in the work-yard, fitted upon the platform in the exact sites they were to occupy in the building, and so marked and numbered that they could readily be restored to their proper relative positions. So much preliminary care having been taken, no difficulty or confusion occurred in the use of the materials, whilst the progress of the building was also greatly accelerated. For the actual details of the manner in which the masonry was proceeded with, we must refer the professional reader to Smeaton's own 'Narrative,' which is remarkably minute, and as a whole exceedingly interesting.

The careful manner in which the details of the foundation work were carried on is related by Smeaton at great length. One of his expedients is worthy of notice—the method by which he gave additional firmness to the stones dovetailed into the rock, by oak-wedges and cement inserted between each. To receive the wedges, two grooves were cut in the waist of each stone, from the top to the bottom of the course, an inch in depth and three inches in width. The carpenters dropped into each groove two of the oaken wedges, one upon its head, the other with its point downwards, so that the two wedges in each groove lay heads and points, on which the one was easily driven down upon the other. A couple of wedges were also pitched at the top of each groove, the dormant wedge, or that with the point upward being held in the hand, while the drift wedge, or that with its point downward was driven with a hammer. The object of this wedging was to preserve the whole mass steady together, in opposition to the violent agitation of the sea. In addition to this, a couple of holes being bored through every piece of stone, one course was further bound to another by oak trenails driven stiffly through, and made so fast that they could more easily be torn asunder than pulled out again. "No assignable power," says Smeaton, "less than would by main stress pull these trenails into two, could lift one of these stones from their beds when so fixed, exclusive of their natural weight, as all agitation was prevented by the lateral wedges."

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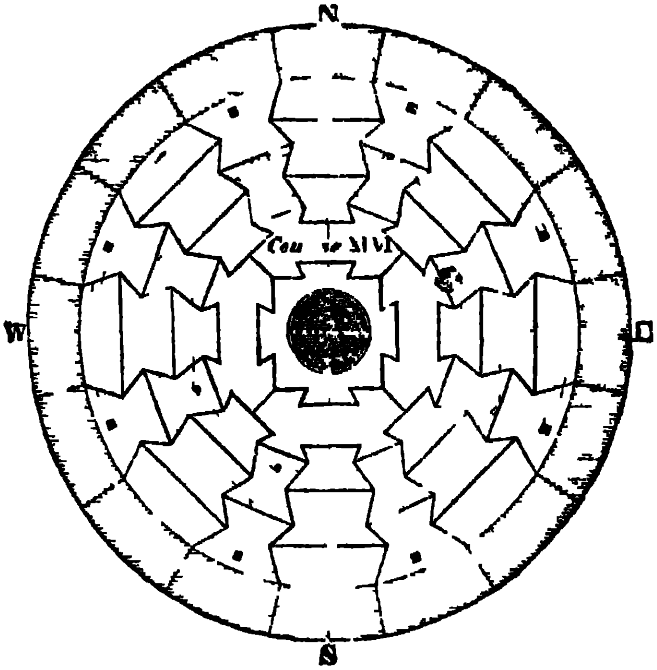
* The sloping form of the rock, to which the foundation of the building was adapted, required only this small number of stones for the lower course; the diameter of the work increasing until it reached the upper level of the rock. Thus the second course consisted of thirteen pieces, the third of twenty-five, and so on.

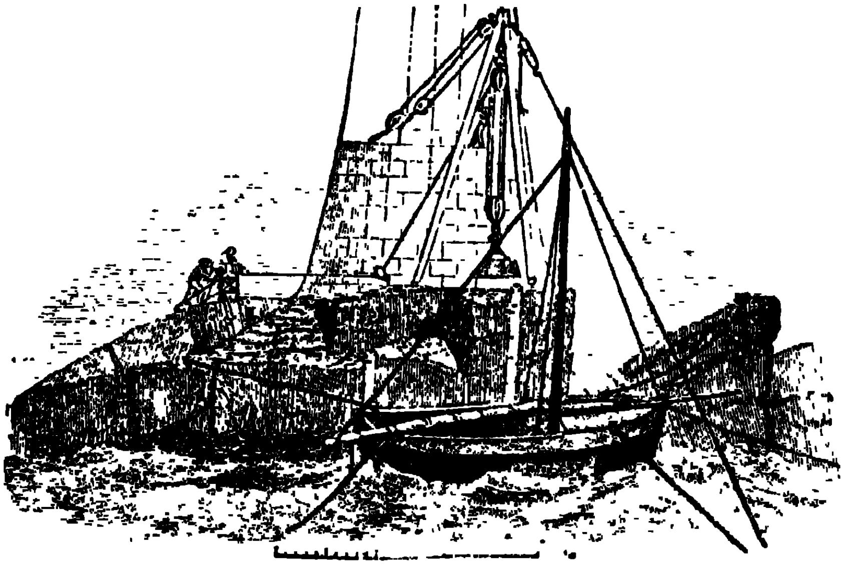


Plan of the 16th course, showing the method of dovetailing.

Mr. Smeaton superintended the construction of nearly the entire building. If there was any post of danger from which the men shrank back, he immediately stood forward and took the front place. One morning in the summer of 1757, when heaving up the moorings of the buss preparatory to setting sail for the rock, the links of the buoy-chain came to a considerable strain upon the davit-roll, which was of cast iron, and they began to bend upon the convexity of the roll. To remedy this, Smeaton ordered the carpenter to cut some trenails into short pieces, and split each length into two, with the view of applying the portions betwixt the chain and the roll at the flexure of each link, and so relieve the strain. But some one said that if the chain should break anywhere between the roll and the tackle, the person that applied the pieces of wood would be in danger of being cut in two by the chain or carried overboard along with it. On this Smeaton, making it a rule never to require another to undertake what he was afraid to do himself, at once stepped forward and took "the post of honour," as he called it, and attended to the getting in of the remainder of the chain, link by link, until the operation was completed.

Whilst working at the rock, an accident occurred to him which might have been attended with serious consequences, but which merely enabled him to display his usual cheerful courage. The men were about to lay the centre stone of the seventh course on the evening of the 11th of August, when Mr. Smeaton was enjoying the limited promenade afforded by the level platform of stone which had with so much difficulty been raised; but, making a false step into one of the cavities made for the joggles, and being unable to recover his balance, he fell from the brink of the work down among the rocks on the west side. The tide being low at the time, he speedily got upon his feet and at first supposed himself little hurt, but shortly after he found that one of his thumbs had been put out of joint. He reflected that he was fourteen miles from land, far from a surgeon, and that uncertain winds and waves lay between. He therefore determined to reduce the dislocation at once; and laying fast hold of the thumb with his other hand, and giving it a violent pull, it snapped into its place again, after which he proceeded to fix the centre stone of the building.

The work now went steadily forward. Occasional damage was done by the heavy seas washing away the stones, tools, and materials; but these losses were quickly repaired, and by the end of the season the ninth course of stones had been laid complete. The following winter was very tempestuous. The floating light-vessel, stationed about two miles from the rock, was driven from its moorings by the force of the sea, but eventually got safe into harbour. It was the 12th of May before another landing could be effected by Smeaton and his workmen, when he was no less delighted than surprised to find the entire work as he had left it six months before. Not a block had been moved. The cement was found to have set as hard as the stone itself, and the whole of the building which had been raised was one solid mass.


Progress of the Works to the 15th course

The rock-tackle, with sheers and windlass, having been again fixed, the erection proceeded as before. The fundamental Solid was completed by the 8th of August; and, the fine weather continuing, the Solid work, which included the passage from the entry-door to the well-hole for the stairs, made great progress; until, on the 24th of September, 1758, the twenty-fourth course was finished; which completed the solid part of the pillar and formed the floor of the storeroom. The building had now been raised thirty-five feet four inches above its base, or considerably beyond the heavy stroke of the waves. Above this point were to be formed the requisite apartments for the lighthouse-keepers. The walls of these were twenty-six inches thick, constructed in circles of hewn blocks, sixteen pieces forming each circle, all joggled and cramped, so as to secure perfect solidity. The stones were further grooved at the ends, and into the grooves tightly-fitting pieces (rhombs) of Purbeck marble were fixed solid with well-tempered mortar, making the whole perfectly firm and water-tight.

While living at Plymouth, Smeaton used to come out upon the Hoe with his telescope, in the early grey of the morning, and stand gazing through it in the direction of the Rock. The Hoe is an elevated promenade, occupying a high ridge of land extending between Mill Bay and the entrance to the harbour, the citadel occupying its eastern end. It forms the sea-front of Plymouth, and overlooks the strikingly beautiful scenery of the Sound. St. Nicholas's Island, strongly fortified, lies immediately in front of it; beyond, rising green from the water's edge, is Mount Edgcumbe Park, with its masses of noble woods backed by green hills. The land juts out in rocky points on either side the bay, some of which are capped with forts and batteries; whilst in the distance lies the magnificent barricade of the Breakwater, midway between the bluffs of Redding and Staddon Points, boldly interposing between the swell of the Sound and the long ocean waves rolling in from the Atlantic.

From the Hoe the Spanish Armada was first descried making for the English coast. It was the look-out of Drake, as it now was of Smeaton, but with a far different object. After a rough night at sea, he had no eye for the picturesque beauties of the Sound: his sole thought was of his lighthouse; for though he had done all that human care, forethought and skill could do, to root his column firmly upon that perilous rock, he was not yet altogether free from anxiety as to the security of the foundation. There were still many who persisted in asserting that no building erected of stone could possibly stand upon the Eddystone, and, again and again, the engineer, in the dim grey of the morning, would come out and peer through his telescope at his deep-sea lamp-post. Sometimes he had to wait long, until he could see a tall white

Smeaton on the Hoe. [By P. Skelton and Heard.]

pillar of spray shoot up into the air, and then a glimpse of the column itself. Thank God! it was still safe. Then, as the light grew, he could discern his building, temporary house and all, standing firm amidst the waters; and, thus far satisfied, he could proceed to his workshops, his mind relieved for the day.

The work proceeded so satisfactorily during the season of 1758, that Smeaton resolved to make a vigorous effort to get the lower storeroom completed, and a light erected above it for use during the ensuing winter. At the beginning of October, the twenty-eighth and twenty-ninth courses were laid, and very strongly secured. A groove was cut round their upper surfaces, in which was placed a circular chain of great strength. Upon each chain, when placed within the grooves, melted lead was poured until the cavities were filled up. They were thus *hooped*, as it were, round the building. The reason of such excessive strength at this part of the work was, that these courses received the vaulted floor which formed the ceiling of the under storeroom and the floor of the upper one.

By the 10th of October, Smeaton had nearly completed all the necessary arrangements for establishing a light and lightkeepers at the Eddystone during the ensuing winter; when he received an unexpected and painful refusal from the Corporation of the Trinity House, to the effect that "on reading the Acts of Parliament, the application from the merchants and owners of ships, and Winstanley's narrative of the first lighthouse erected there, they are of opinion that a light cannot be exhibited on the Eddystone Rock till the lighthouse is rebuilt." Smeaton was, therefore, under the necessity of erecting merely a temporary house over the work for its protection during the winter; when he speeded off to London to finish his further drawings.

The third year's operations had now ended, and the engineer proceeded with the designs for the iron rails of the balcony, the cast and wrought iron and copper works, as well as with the glass for the lantern, all of which were, like the rest of the work, manufactured under his own eye. The year 1759 was so stormy that it was not before the 5th of July that the workmen could land upon the rock, and recommence their building operations for the year; but from this point they proceeded with great rapidity,—the whole of the stones being now in readiness to be placed—so that in thirteen days two entire rooms with their proper coverings had been erected; and by the 17th of August the last pieces of the corona were set, and the forty-six courses of masonry were finished complete.

The column was now erected to its specified height of seventy feet. The last mason's work done was the cutting out of the words "LAUS DEO" upon the last stone set over the door of the lantern. Round the upper storeroom, upon the course under the ceiling, had been cut, at an earlier period, "Except the Lord build the house, they labour in vain that build it." The iron work of the balcony and the lantern were next erected, and over all the gilt ball, the screws of which Smeaton fixed with his own hands, "that in case," he says, "any of them had not held quite tight and firm, the circumstance might not have been slipped over without my knowledge." Moreover this piece of work was dangerous as well as delicate, being performed at a height of some hundred and twenty feet above the sea. Smeaton fixed the screws while standing on four boards nailed together, resting on the cupola; his assistant, Roger Cornthwaite, placing himself on the opposite side, so as to balance his weight whilst he proceeded with the operation.

The engineer's work was now so nearly ended, and his anxiety had become so great, that he could not leave it, but took up his abode in the lighthouse, putting his own hands to the finishing of the window-fittings (for skilled workmen were difficult to be had at the lighthouse) and seeing to the minutest details in the completion of the undertaking. At length the lantern was glazed, the lightning-conductor fixed, the rooms were fitted up, and the builder looked upon the work of his hands as finished and complete. The light was first exhibited on the night of the 16th of October, 1759, and the column still stands as firm as on the day on which it was erected.* About three years after its completion, one of the most terrible storms ever known raged for days along the south-west coast; and though incalculable ruin was inflicted upon harbours and shipping by the hurricane, all the damage done to the lighthouse was repaired by a little gallipot of putty.

The Eddystone Lighthouse has now withstood the storms of more than a century. Sometimes, when the sea rolls in with more than ordinary fury from the Atlantic, driven up the Channel by the force of a south-west wind, the lighthouse is enveloped in spray and its light is momentarily obscured. But again it is seen shining clear like a star across the waters, a warning and a guide to the homeward-bound. Occasionally, when struck by a strong wave, the water shoots up the perpendicular shaft and leaps quite over the lantern. At other times, a tremendous wave hurls itself upon the lighthouse, as if to force it from its foundation. The report of the shock to one within is like that of a cannon: the windows rattle, the doors slam, and the building vibrates and trembles to its very base. But the tremor felt throughout the lighthouse in such a case, instead of being a sign of weakness, is the strongest proof of the unity and close connection of the fabric in all its parts.*

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* Since the issue of the first edition of this work, a relative of the late General the Hon. Henry Murray, K.C.B., Lieutenant-Governor of Plymouth, has sent us the following extract from a letter of his written in 1848, relative to the stability of Smeaton's lighthouse:—"I heard a curious thing mentioned the other day, but it was on good authority. Mr. Walker, the Harbour Master of Plymouth, has to make an annual inspection of the Eddystone Lighthouse. Not long ago, it struck him as a thing to be ascertained, whether the building was exactly perpendicular. For this purpose he let fall a plummet, and found that the building was a *quarter-of-an-inch off the perpendicular,* towards the North-east side. This he thought an alarming thing, as it might be the symptom of a settlement taking place in the foundation. I believe he made a report upon the subject. But happening to look into a 'Life of Smeaton,' who constructed the Lighthouse, he found a record in his diary or journal to this effect: 'This day, the Eddystone Lighthouse has, thank God, been completed. It is, I believe, perfect; except that it inclines a quarter-of-an-inch from the perpendicular towards the North-East;' thus, in the long lapse of time since it was built, it stands precisely as it stood at the moment of its completion."

Many a heart has leapt with gladness at the cry of "The Eddystone in sight!" sung out from the maintop. Homeward-bound ships, from far-off ports, no longer avoid the dreaded rock, but eagerly run for its light as the harbinger of safety. It might even seem as if Providence had placed the reef so far out at sea as the foundation for a beacon such as this, leaving it to man's skill and labour to finish His work.

On entering the English Channel from the west and the south, the cautious navigator feels his way by early soundings on the great bank which extends from the Channel into the Atlantic, and these are repeated at fixed intervals until land is in sight. Every fathom nearer shore increases a ship's risks, especially in nights when, to use the seaman's phrase, it is "as dark as a pocket." The men are on the look-out, peering anxiously into the dark, straining the eye to catch the glimmer of a light, and when it is known that "the Eddystone is in sight!" a thrill runs through the ship, which can only be appreciated by those who have felt or witnessed it after long months of weary voyaging.* Its gleam across the waters has thus been a source of joy and given a sense of deep relief to thousands; for the beaming of a clear light from one known and fixed spot is infallible in its truthfulness, and a safer guide for the seaman than the bearings of many hazy and ill-defined headlands.

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* At first the men appointed as light-keepers were much alarmed by the fury of the waves during storms. The year after the light was exhibited, the sea raged so furiously that for twelve days together it dashed over the lighthouse, so that the men could not open the door of the lantern. In a letter addressed to Mr. Jessop by the man who visited the rock after such a storm, he says:—"The house did shake as if a man had been up in a great tree. The old men were almost frightened out of their lives, wishing they had never seen the place, and cursing those that first persuaded them to go there. The fear seized them in the back, but rubbing them with oil of turpentine gave them relief." Since then, custom has altogether banished fear from the minds of the lighthouse keepers. The men become so attached to their home, that Smeaton mentions the case of one of them who was even accustomed to give up to his companions his turn for going on shore.

By means of similar lights, of different arrangements and of various colours, fixed and revolving, erected upon rocks, islands, and headlands, the British Channel is now lit up along its whole extent, and is as safe to navigate in the darkest night as in the brightest sunshine. The chief danger is from fogs, which alike hide the lights by night and the land by day. Some of the homeward-bound ships entering the Channel from North American ports first make the St. Agnes Light, on the Scilly Isles, revolving once in a minute, at a height of 138 feet above high water. But most Atlantic ships keep further south, in consequence of the nature of the soundings about the Scilly Isles; and hence they oftener make the Lizard Lights first, which are visible about twenty miles off. These are two in number, standing on the bold headland forming the most southerly point of the English coast, against which the sea beats with tremendous fury in south-westerly gales.†

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* A seaman of great experience who furnished us with the statement of the lights seen in going "up Channel" in 1862 (for several alterations may have occurred since then), makes the following observations:—'I ought to say, with feelings of deep gratitude, that, notwithstanding every precaution of soundings, &c., I have, on two occasions, saved my ship by means of the Eddystone light and, without its star gleaming through the darkness, all on board must inevitably have perished. This occurred at a time when I felt thoroughly master of my profession, had first-rate officers by my side, and a splendid crew and ship, yet, had Smeaton failed to erect his lighthouse, our lot must have been a watery grave."

† Since the first edition of this work appeared, the Wolf Rock

From this point the coast retires, and in the bend lie Falmouth (with a revolving light on St. Anthony's Point), Fowey, the Looes, and Plymouth Sound and Harbour; the coast-line again trending southward until it juts out into the sea, in the bold craggy bluffs of Bolt Head and Start Point, on the last of which is another house with two lights,—one revolving, for the Channel, and another, fixed, to direct vessels inshore clear of the Skerries shoal. But between the Lizard and Start Point, which form the two extremities of this bend in the land of Cornwall and Devonshire, there lies the Eddystone Rock and Lighthouse, standing fourteen miles out from the shore, almost directly in front of Plymouth Sound and in the line of coasting vessels steaming or beating up Channel. From this point the Channel gradually contracts, and the way becomes lighted on both sides up to the Downs.

On the south are seen the three Casquet Lights on the Jersey side; and on the north the two fixed lights on Portland Bill. The next is St. Catherine's, a brilliant fixed light on the extreme south point of the Isle of Wight. Next are the lights exhibited at different heights on the Nab, and then the single fixed light exhibited on the Owers vessel. Beachy Head, on the same line, exhibits a powerful revolving light 285 feet above high water, its interval of greatest brilliancy occurring every two minutes. Then comes Dungeness, exhibiting a fixed red light of great power, situated at the extremity of the low point of Dungeness Beach. Next are seen Folkestone, and then Dover, harbour lights; whilst on the south are the flash light, recently stationed on the Varne Bank; and, farther

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Lighthouse has been erected on a dangerous rock, situated seven miles south-west of Land's End, and about 22 miles from the Scilly Islands on one side, and the Lizard Point on the other. The extreme height of the masonry of the tower is 116 feet 6 inches, the lantern being 19 feet high, and 11 feet diameter. The lighthouse was erected after the plans of the late James Walker, C.E.

up Channel, on the French coast, is seen the brilliant revolving light on Cape Grisnez.

The Channel is passed with the two South Foreland Lights, one higher than the other, on the left; and the Downs are entered with the South Sandhead floating light on the right; and when the Gull and the North Sandhead floating lights have been passed on the one hand, and the North Foreland on the other, then the Tongue, the Prince's Channel, and the Girdler, are passed. The Nore Light comes next in sight, and from thence it is as easy for the navigator to pilot his ship up the Thames as for a foot-passenger to thread his way along the streets of London. Such in a few words is the admirable manner in which our coasts are lighted up for the guidance of the mariner, and such are among the benefits to navigation which have followed close upon Smeaton's great enterprise—the building of the Eddystone Lighthouse.

The Light at the Nore. By [illegible] Leitch.

CHAPTER V.

MR. SMEATON'S EMPLOYMENT AS A CIVIL ENGINEER.

THE completion of the Eddystone Lighthouse was regarded as a matter of much interest, and excited so eager a curiosity on the part of the public, that for some time Mr. Smeaton's rooms at Gray's Inn were the resort of numerous visitors, who called there for the purpose of inspecting the model of his extraordinary building. This at length so broke in upon his time, that he found it necessary to depute his wife to attend to these curious persons, and explain to them the details of the model. It does not, however, appear that his success led to his extensive employment on engineering works for several years, otherwise we should not have found him, in 1764, offering himself a candidate for the receivership of the Derwentwater Estates, to which office he was appointed at the end of that year.

There was as yet, indeed, but small demand for constructive skill. The roads were still in a very bad state, bridges were much wanted in most districts, and little had been done to provide harbour accommodation beyond what nature had effected. The country was too poor or too spiritless to undertake the improvement of the means of commercial intercourse on any comprehensive scale. The industrial enterprise of England had not yet begun; and the country was content to jog along in its old paths, displaying its energies principally in warfare by land and sea. The victory of Wolfe on the heights of Abraham occurred in the same year that Smeaton completed his lighthouse on the Eddystone, and doubtless excited a far more general interest.

It is true the trade and commerce of the country were making some progress,* though both had to labour under serious imposts and heavy restrictions. The public expenditure was great, provisions were dear in proportion to wages, and food-riots were frequent. Under these circumstances internal improvements, involving any considerable outlay, were of a very limited character. When Smeaton was called upon to examine an undrained district, or a dangerous and inaccessible harbour, or a decaying bridge, he had little difficulty in advising what was best to be done; for his reports were searching, explicit, and almost exhaustive. But then arose the invariable impediment. The requisite improvements could not be executed without money; but money was scarce, and could not be raised. Hence the greater number of his reports, though containing much excellent and carefully-considered advice, fell dead upon the minds of those to whom they were addressed; and no action was taken to carry them into effect until the country had become richer, and a new race of capitalists, engineers, and contractors had sprung into existence.

One of the earliest subjects on which Mr. Smeaton was consulted, was the opening up of river navigations. In 1760 he reported to the magistrates of Dumfries as to the improvement of the Nith; but his advice—to form a navigable canal rather than deepen and straighten the river at a much greater cost—was not carried out for want of funds. He was also consulted as to the lockage of the Wear, the opening up of the navigation of the Chelmer to Chelmsford, of the Don above Doncaster, of the Devon in Clackmannanshire from Melloch Foot to the Forth, of the

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* It may, however, be questioned whether the trade of England *did* make progress during the twelve years ending 1762; for we find that, although the value of the cargoes exported increased about a million sterling during that period, the quantity exported was less by 60,000 tons. (See 'Chalmers's Estimate,' p. 131.)

Tetney Haven navigation near Louth, and the improvement of the river Lea, which has been a fertile source of contention amongst engineers down even to our own day; but it does not appear that any works of importance followed the elaborate advice which Smeaton gave on those subjects.

The first engineering undertaking on which he was employed was in his own native county, where he was required to make extensive repairs in the dams and locks on the river Calder in Yorkshire. He carried out several essential improvements in that navigation, for the purpose of resisting the damage caused to the works by the rapid floods which swept down from Blackstone Edge. At the same time he was consulted as to the Aire navigation, from Leeds to its junction with the Ouse, which he also succeeded in improving.

Another subject on which he was early and often consulted was the recovery of the flooded ground in the Lincoln Fens, and in the low-lying lands near Doncaster and Hull, in Yorkshire. The river Witham, between Lincoln and Boston, was still a source of constant grief and loss to the farmers along its banks. It had become choked up by neglect, so that not only had the navigation of the river become almost lost, but a large extent of otherwise valuable land was constantly laid under water. In reporting on this subject in 1761, Mr. Smeaton was associated with Mr. John Grundy and Mr. Langley Edwards; and the result of their joint examination was an elaborate report, accompanied by plans, in which they clearly pointed out the causes of the existing evils and the best mode of remedying them. For the purpose of improving the outfall, they recommended the cutting of an entirely new river, about twelve and a half miles in length, from a place called Chapel Hill to a little above Boston. They also at the same time recommended a plan for the drainage of Wildmore and West Fens by a new cut and sluice in place of the old Anthony's Gout, with sundry other improvements which they set forth in detail. But the total estimated cost being upwards of 40,000*l.*, which was then considered a "mint of money" for a comparatively poor county to raise, the recommendation of the consulting engineers produced no result; and the greater part of the lands remained drowned until they were effectually cleared of their surplus water by Mr. Rennie, about half a century later.

Mr. Smeaton was also consulted, in 1762, about the improvement of the Fossdyke, an old cut joining the Trent and the Witham, which had been allowed to fall into decay; but only a few pottering improvements were made, in lieu of the thorough measure of general drainage which he so strongly recommended. After the lapse of twenty years Mr. Smeaton was again called in, and further advised the proprietors on the subject; but although he then submitted a much more limited scheme, it was still beyond the capability of the county to undertake it.

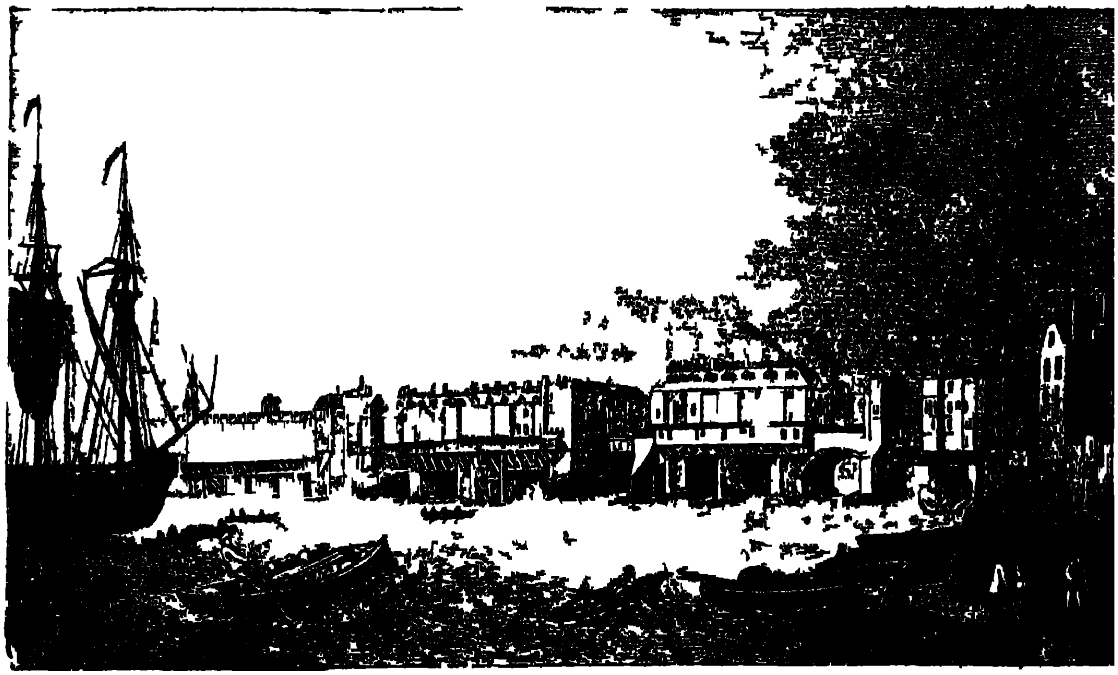
At a still later period he was consulted as to the drainage of the North Level of the Fens, and the improved outfall of the river Nene at Wisbeach. In his report on this subject, he went at great length into the probable causes of the flooding of the fens, and from these he reasoned out the improvements necessary for their effectual cure. The principal measure which he proposed was, to build a powerful outfall sluice upon the mouth of the Nene. In this report he brought the observations which he had made while on his journey through the Low Countries to bear upon the case; and he argued that, as the outfall channels at Middlesburgh and Ostend were kept wholly open by sluices, the same method would equally apply at Wisbeach. But, like his predecessor Vermuyden, Smeaton did not seem sufficiently to take into account the different circumstances of the two tracts of country; and it is perhaps fortunate that his plans were not carried out, as subsequent experience has shown [illegible] if executed, they would most probably have proved injurious.

Considerable success, however, attended his operations [illegible] improving the drainage of the Isle of Axholme, originally executed by Vermuyden. The lower lying lands in the district had fallen into a wretched condition, through neglect of the river outfalls, and when Smeaton was consulted as to a remedy, he advised the diversion of the old river Torne, which was carried out, and, where not diverted, it was widened and deepened. The result was satisfactory, though, many years after, we find Mr Rennie describing the drainage as still very imperfect, and urgently demanding an effectual remedy.

It would occupy too much space to detail the works of a similar kind on which Mr Smeaton was consulted. We may content ourselves with merely mentioning the more important, which were these: the drainage of the lands adjacent to the river Went, in Yorkshire, the Earl of Kinnoul's lands lying along the Almond and the Tay in Perthshire, the Adling Fleet Level, at the junction of the Ouse and the Trent, Hotham Carrs, near Market Weighton, the Lewes Laughton Level, in Sussex, the Potterick Carr Fen, near Doncaster, the Torksey Bridge Fen, near Gainsborough, and the Holderness Level, near Hull. These works, though of a highly useful character, possess but small interest in a narrative, and we therefore proceed to describe the undertakings of a different character on which our engineer was about the same time employed.

Having fully proved his mastery of the art of construction, and his skill in overcoming the difficulties arising from insecure foundations, by his erection of the Eddystone Lighthouse, he was frequently called upon for advice [illegible] the repairs of old bridges, as well as the erection of new ones. Thus, in 1762, we find him consulted as to the [illegible] of Bristol Old Bridge, and in the following year [illegible] called upon by the Corporation of London to advise [illegible] to the best means of improving, widening, and enlarging Old London Bridge. Although considerable alterations and improvements had been made in it, the structure was in a very rickety state, and was a source of constantly recurring alarm to the public.

When Labelye's New Westminster Bridge was opened for traffic in 1749, the defects of London Bridge became more apparent than ever. The Corporation even went so far as to entertain a project for rebuilding it. The city surveyor, however, after examining the foundations of the piers in 1754, declared them still to be good, and capable of lasting for ages! His report relieved the public anxiety for a time, and the old patching process went on as before. The bridge was still overhung with houses on either side, and the roadway between them was very narrow and dark.



Old London Bridge before the alteration of 1758. [After the painting by Samuel Scott.]

Labelye's opinion was then taken as to the improvement of the structure, and he recommended the removal of the starlings which so blocked up the waterway as to cause a fall of nearly five feet between the piers, during the greater part of every tide. He also advised the removal of some of the piers, as had been recommended by Sir Christopher Wren, and throwing several of the arches together. The discussions of the Common Council, however, ended in the proposal to erect a new bridge at Blackfriars, and the removal at the same time of the houses from the old bridge, both of which measures were eventually carried out. The great middle pier was also removed, and the two adjoining locks were thrown into one by turning a new arch, which occupied the whole space.

Old London Bridge after the removal of the Houses [By E. M. Wimperis.]

It was now found, however, that the increased scour of the water passing under the new archway placed the adjoining piers in great peril, by washing away the bed of the river under their foundations. The apprehensions of danger were such that but few persons would pass either over or under the bridge, and the Corporation, becoming alarmed, sent in all haste for Mr. Smeaton. He was then living at his house at Austhorpe, near Leeds, from whence he was summoned by express to town. On his arrival, he proceeded to survey the bridge and examine the foundations which were giving way. His advice to the Corporation was, to buy back immediately the stones of the City gates, which had recently been taken down and the materials sold, and throw them into the river outside the starlings, for the purpose of protecting them against the scour of the river. Another object of this measure, as explained in Smeaton's reports, was to restore the old dam by again raising a barrier of stones across the waterway, and thus increase the head of the current under the other arches, so as to drive the wheels, by means of which a considerable part of the water required for the supply of the City, was still raised.

Smeaton's recommendations were adopted as the most advisable course to be pursued under the circumstances; and horses, carts, and barges were at once set to work, and the stones were tumbled into the stream at the base of the tottering piers. By these means the destruction of the foundations was temporarily stayed, and the process of patching up the old bridge went on from time to time for sixty years more; until it was at length effectually remedied by the erection of New London Bridge.

In connection with the bridge works, Smeaton also furnished a design for a new pumping-engine, which was placed in the fifth arch, and worked by the rise and fall of the tide. Before the invention of the steam-engine, this was an economical though an irregular method of obtaining motive power. The same tides that lifted great ships up the river and let them down again twice in each day, then drove pumping-engines and even flour-mills—the driving-wheels turning one way as the tide rose, and another way as it fell.* This power was, however, shortly superseded by the still more economical power of steam: for the steam-engine, though involving a considerable expenditure of coal, proved cheaper in the end, because it was so much more certain, regular, and expeditious than the natural power of the tides.

The bridges erected after Smeaton's original designs, were those of Perth, Coldstream, and Banff: the only one which he erected in England being at Hexham, in Northumberland, which proved a failure. He was consulted about the new bridge at Perth as early as the year 1763, when he visited the place, fixed upon the best site for the structure, and afterwards furnished the design, which was carried into effect. The river Tay being subject to sudden floods in one of which a former bridge had been swept away it was necessary to take every precaution with the foundations, which were got in by means of coffer-dams. That is, a row of piles was driven into the bed of the river, on which a quantity of "gravel and even mould earth mixed together" was thrown in all round the piles, with a view to render the enclosed space impervious to water. Pumping power was then applied, and the bed of the river was laid dry within the coffer-dam thus formed, after which the gravel or clay was dug out to a proper depth, until a solid foundation was secured for the piers. Piles were driven into the earth under the intended foundation-frame, and the building proceeded upward in the usual way.* The bridge is a handsome structure, consisting of seven principal arches, and is about 900 feet in length, including the approaches. It was completed and opened for traffic in 1772, and has proved of great service to the locality.

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* 'Encyclopedia Metropolitana,' vii. 139.

Smeaton's employment at Perth on this occasion introduced him to a considerable amount of engineering business in the North. He was consulted at Edinburgh respecting the improved supply of water for that city, and at Glasgow about the security of its old bridge. But the most important work on which he was employed in Scotland, about this time, was the designing and construction of the Forth and Clyde Canal for connecting the navigation of the eastern and Western seas. The success of the Duke of Bridgewater's Canal had directed public attention in all parts of the kingdom to the formation of similar lines of internal communication; and the movement had also extended to Scotland.

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* It may be worthy of remark that John Gwin, the person recommended by Smeaton to conduct the trial borings for the foundations, took with him two experienced men from England to conduct the works, stipulating that they should each receive wages at the rate of 11s. a week.

James Watt, then carrying on a small business as a mathematical instrument maker in Glasgow, had been employed to survey a "ditch canal," of a very limited capacity, by a round-about route, through the Perthshire lochs; but his genius being as yet unrecognised, the projectors thought it desirable to call in an engineer of higher standing, and Smeaton was accordingly consulted by them in 1764. He had before been employed to examine the Grand Trunk line, as surveyed by Brindley, and his report on the subject was regarded as a very able one. Brindley was also consulted respecting the Forth and Clyde scheme, but his time was so much occupied with the projects which he was engaged in carrying out in the western counties of England, that he could not undertake the working survey; and it was accordingly placed in the hands of Smeaton. He reported upon the several schemes which had been proposed for connecting the Forth with the Clyde, and advocated the plan which in his judgment was the best calculated to carry out the intentions of the projectors. He declared himself in favour of forming the most direct line across the country between the two Friths, of such a capacity as to accommodate vessels of large burden.

Lord Dundas, the leading promoter of the scheme, adopting the view put forward by the engineer, took the requisite steps to obtain an Act authorising the construction of the Forth and Clyde Canal, which passed accordingly, and the works were commenced in 1768. The canal runs almost parallel with the line of the wall of Antoninus, built by the Romans to restrain the incursions of the Caledonian tribes, many vestiges of which are still traceable along the canal, and at Bowling,* the point at which the main canal joins the Clyde, a few miles below Glasgow.

The canal is about 38 miles in length, and includes 39 locks with a rise of 156 feet from the sea to the summit level. It was one of the most difficult works of the kind which had, up to that time, been constructed in the kingdom. The engineer had to encounter numerous rocks and quicksands. The canal in some places passed over deep rivers, and at others along embankments more than 20 feet high. It crossed many roads and rivulets, and two rivers, the Luggie and the Kelvin, - the bridge over the latter being 275 feet long and 68 feet high. The depth of the canal was 8 feet, and vessels of 19 feet beam and 68 feet keel were capable of easily passing through it, between the east and west coasts.

Although the total cost of the undertaking was estimated at only about 150,000*l.*, and the important uses of the navigation were unquestionable, the greatest difficulty was experienced in raising the requisite funds; and long before the canal could be opened to the Clyde, the works came to a complete stand-still. Twenty years passed before the money could be raised to finish them, and this was only effected by the aid of a public grant. At length the canal was opened in 1790, having been finished by Mr. Whitworth (one of Brindley's pupils), and the opening of the communication between the eastern and western oceans was celebrated with great rejoicings,—the Chairman of the Canal Committee performing the feat by launching a hogshead of water brought from the Forth into the Clyde.

Mr. Smeaton was next employed to build a bridge across the Tweed at Coldstream. He furnished several designs. and that eventually selected by the trustees was executed under his superintendence. It consisted of five principal arches of the segment of a circle, the centre one being 60 feet 8 inches from pier to pier, the two next, 60 feet 5 inches, and the two land or side arches, 58 feet. The design presents no features worthy of special notice, nor was any unusual difficulty experienced in getting in the foundations. The piers were founded on piles driven deep into the bottom of the river, and the building, where beneath the level of the stream, was carried on, as at Perth, within coffer dams. To give additional protection to the piers during winter time, when heavy floods sweep down the valley of the Tweed, they were surrounded by strong sheet piling* as well as by rubble slopes pointing up-

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* The traces of the wall and ditch of Antoninus, are still extremely distinct at many places between Boroughstoness and Glasgow—more particularly at Kirkintilloch and Castlecary.

Coldstream Bridge. [By J. M. Wimperis, after a Drawing by J. S. Smiles.]

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* Sheet piling consists of a row of timbers driven firmly side by side into the earth, and is used for the protection of foundation-walls or piers from the effects of water. Cast iron is now employed in many cases for the same purpose, instead of timber.

The bridge was finished at a total cost of about 6000*l.*, and was opened for carriage traffic in October 1766, having been rather more than three years in building.

Whilst engaged on his engineering business in Scotland, Mr. Smeaton formed the acquaintance of Dr. Roebuck, the enterprising but unfortunate projector of the Carron Iron Works, near Falkirk. That gentleman was one of the first who attempted to develope the iron trade of Scotland, which has since become so important. He was then engaged in the double task of carrying on iron works at Carron and working coal-mines at Borrowstonness. Dr. Roebuck was a man full of expedients, and possessed an uncommon knowledge of mechanics. Smeaton was a kindred spirit, whom he very early sought out and invited to his house at Kinneil, near Borrowstonness, for the purpose of consulting him as to the pumping machinery of his mines, and the various arrangements of his iron manufactory at Carron.

Dr. Roebuck was one of the first to employ coal in iron-smelting on a large scale, and for that purpose he required the aid of the most powerful blowing apparatus that could be procured. Mr. Smeaton succeeded in contriving and fixing for him, about the year 1768, a highly effective machine of this kind, driven by a water-wheel.* He also supplied the same Company with a design for a double-boring mill for cylinders and guns—the manufacture of carronades, or "smashers," having been an early branch of the business at Carron Works. At the same time Smeaton pointed out how the water power of the little river Carron might be so concentrated and increased by damming, as to work the apparatus he contrived with the greatest possible effect. He was afterwards repeatedly consulted by the Carron Company as to the manufactures carried on at the works—such as the making of shot-moulds, the best form of slide-carriages for guns, the construction of furnaces, and such like matters, of which the plans and descriptive details are to be found in his published reports.*

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* The author endeavoured to obtain an inspection of this long-disused apparatus, for the purposes of this work, in the autumn of 1858; but the reply of the manager was, "Na, na, it canna be allowed—we canna be fashed wi' strangers here." Burns, the poet, also attempted, in vain, to visit Carron Works in 1787; and afterwards wrote the following lines "on a Window of the Inn at Carron."—

We cam na here to view your warks
In hopes to be mair wise,
But only, lest we gang to h——,
It may be nae surprise.

But whan we tirled at your door,
Your porter dought na hear us;
Sae may, should we to h—'s yetts come,
Your billy Satan sair us!

Another fine bridge, of which Smeaton furnished the design in the year 1772, was that subsequently erected over the river Deveron, near the town of Banff, in Scotland. It is of seven arches, segments of circles, and is of the total length of 410 feet between the abutments, with a roadway 20 feet wide over all. The design is similar in most respects to those of the bridges previously erected by the same engineer at Perth and Coldstream; and the beauty of its situation, in the immediate vicinity of Duff House, the mansion of the Earl of Fife, and its noble surrounding grounds, render it an object of even greater pictorial interest.

The only peculiarity to be noted in the designs of Smeaton's bridges, is the circular perforations left in the spandrels of the arches, somewhat after the method adopted by Edwards at Pont-y-Pridd, and in several Continental bridges. This had the effect of lightening the weight which pressed upon the piers and on their foundations, and was doubtless an advantage. He also invariably adopted segmental or elliptical in preference to semi-circular arches, probably because of the less cost of bridges after the former design. Much ability was displayed by our engineer in the designing of his centres, which have been much admired for their strength as well as economy of material.

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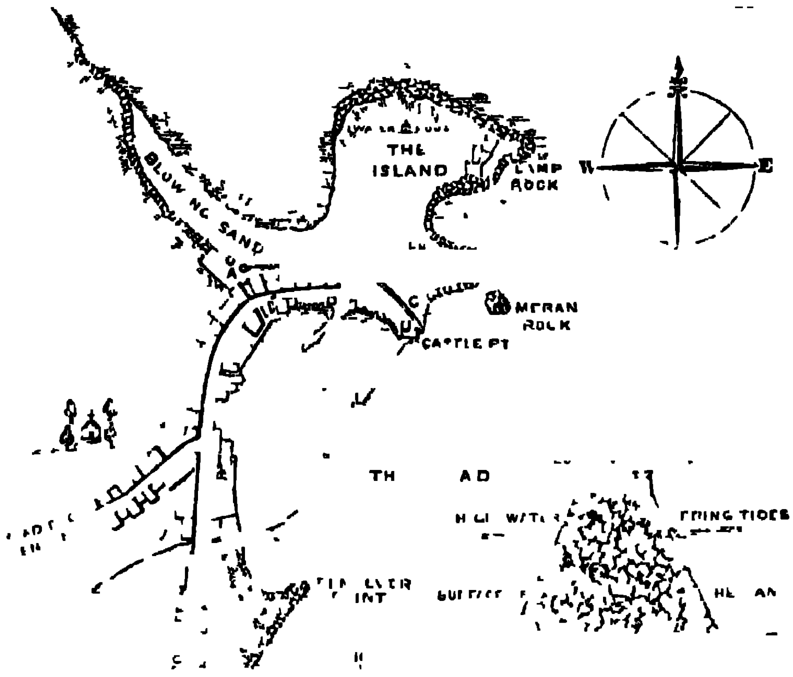
* 'Reports of the late John Smeaton, F.R.S. in 3 vols. London 1812. Vol. i., pp. 359-412.

Banff Bridge [By R. P. Leitch.]

Smeaton was much less successful in the construction of his only English bridge, than he was with his Scotch ones. He was called upon to furnish the design for a structure across the Tyne at Hexham, in 1777, and a very handsome bridge of nine arches was erected, under the superintendence of Mr. Pickernell, the resident engineer. It had scarcely been finished ere a subsidence in the foundations of one of the piers took place, which was attempted to be remedied by sheet-piling and filling up the cavities in the river's bed with rough rubble-stones. But it appeared that the foundations had been imperfectly laid from the beginning. In the spring of 1782 a violent spate swept down the Tyne, and in the course of a few hours Smeaton's beautiful Hexham Bridge lay a wreck in the bottom of the river.

Writing to Pickernell, he said, "All our honours are now in the dust! It cannot now be said that in the course of thirty years' practice, and engaged in some of the most difficult enterprises, not one of Smeaton's works has failed! Hexham Bridge is a melancholy instance to the contrary." Thus the same engineer who had founded a lighthouse far out at sea, so firmly as to bid defiance to the utmost fury of the waves, was baffled by an inland stream. "The news came to me," he says, "like a thunderbolt, as it was a stroke I least expected, and even yet I can scarcely form a practical belief as to its reality. There is, however, one consolation that attends this great misfortune, and that is, that I cannot see that anybody is really to blame, or that anybody is blamed; as we all did our best, according to what appeared, and all the experience I have gained is, not to attempt to build a bridge upon a gravel bottom in a river subject to such violent rapidity."

The fault committed seems to have been, that Smeaton was satisfied with setting his piers upon a crust of gravel slightly beneath the bottom level of the river, and that the increased scour of the stream under the arches, caused by the contraction of the waterway, had washed away the bottom, and thus undermined the work.* But the founding of piers in deep rivers was as yet very imperfectly understood; and the art was not brought to its perfection until the time of Rennie, who went down through the bed of the river, far beneath all possible scour, until he had reached a solid foundation, which he also piled, and on that secure basis he planted the strong masonry of his piers.



Plan of St. Ives Harbour.

Among his various works, Smeaton was also employed in the designing of harbours. With the exception, however, of Ramsgate, these were for the most part confined to the improvement of the existing accommodation. At St. Ives, in Cornwall, where he formed his first harbour, in 1766, nature had provided a convenient haven, enclosed in a bay between two headlands, one of which was formed by "the Island," and the other by Penolver Point, as shown in the preceding plan. It was well protected from the north, west, and south, and from the prevalent storms along the coast, which mostly blow from a south-westerly direction. All that was wanted to give shelter for shipping from the remaining quarters, the east and north-east, was the provision of a pier running nearly south from Castle Point. The works were carried out after Smeaton's design;

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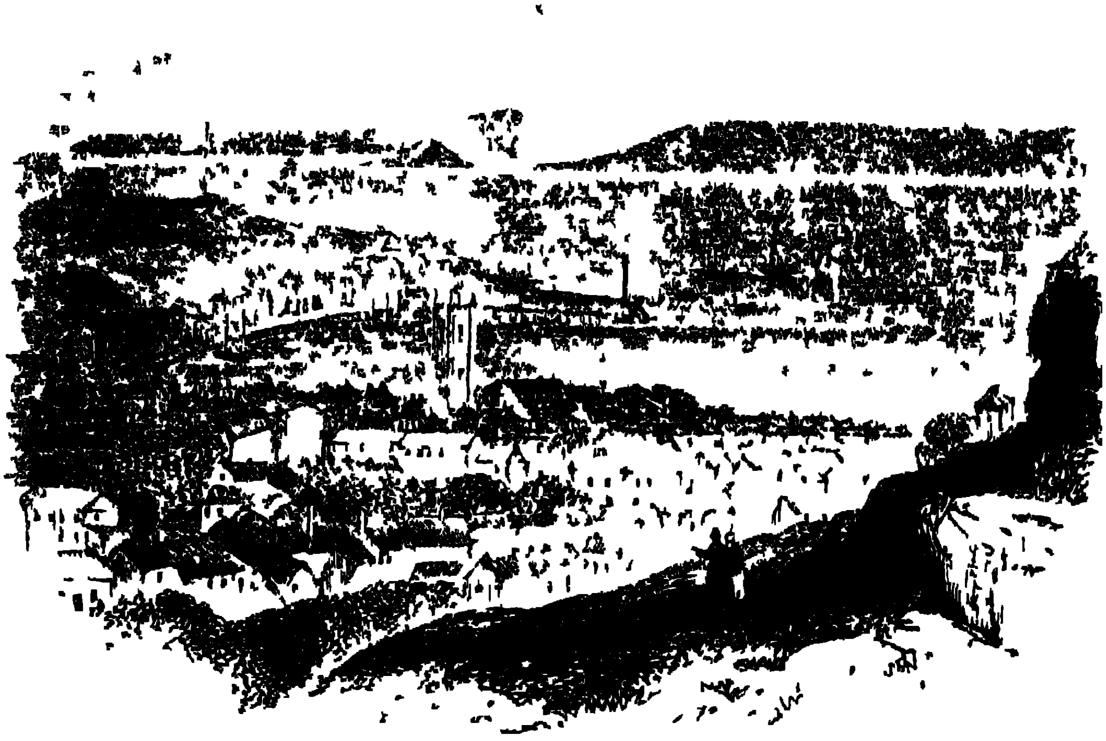
* Not only is the surface of a fluid mass which passes between two piers, and within any narrowing of the bed in general, raised on the up-stream side, as we have just seen, but it is also lowered in the narrow space, and even a little beyond. In consequence of the total fall, the water a little below the narrow space possesses a velocity sensibly greater than before. With this greater velocity, a greater inclination and a less depth, it will more easily reach the bottom, and will there exert a more powerful action. It will, therefore, be below the contracted way that the current will tend more particularly to hollow out the bed, and to undermine the masonry which confines it. The contraction which occurs at the entrance of each of the arches of a bridge, occasions there not only one, or, more often, two superficial converging currents, but also, it causes inferior currents, thought to be more rapid and injurious



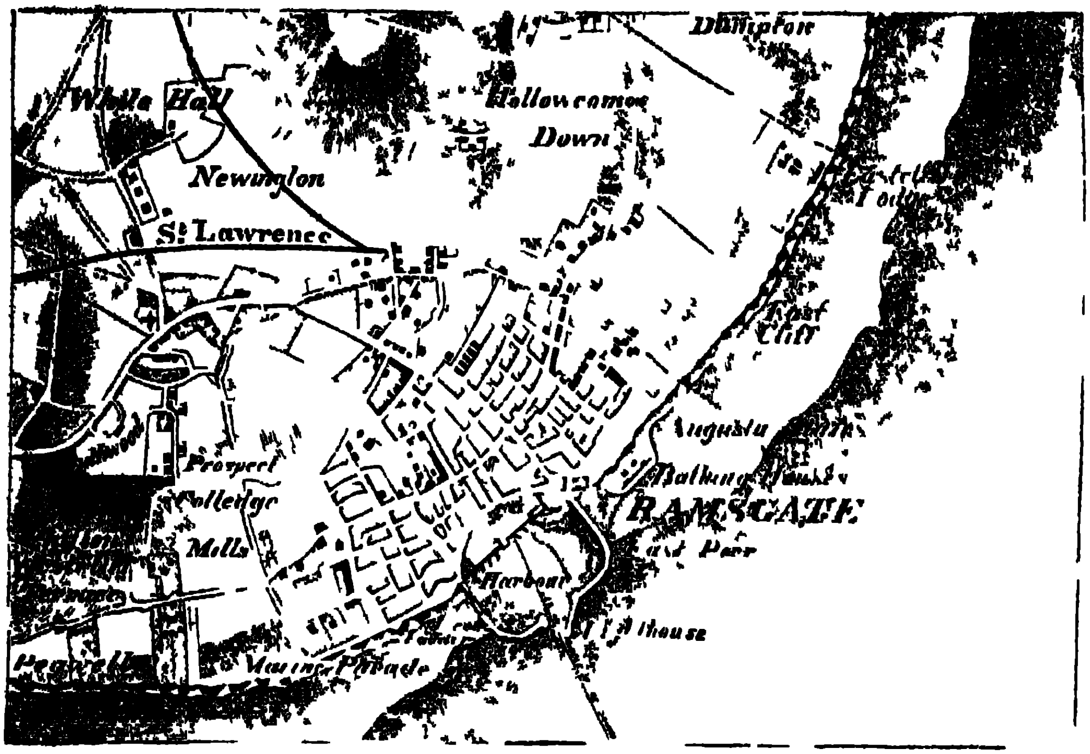
St. Ives Harbour [By E. M. Wimperis.]

and as the port is the seat of considerable trade, arising from the pilchard fishery and the mining operations of the country inland, the facilities thereby provided for shipping, and the protection to navigation along the coast, proved of great advantage to the district.

Our engineer was also consulted respecting numerous other harbours: Whitehaven, Workington, and Bristol, on the west coast; Christchurch, Rye, and Dover, on the south; and Yarmouth, Lynn, Scarborough, and Sunderland, on the east; but in nearly every case, want of money prevented the improvements suggested by him from being fully carried out. This was pre-eminently the case at Bristol, where the merchants gave him an unanimous "vote of thanks" for his report and plan for keeping the ships at the quay constantly afloat by docking the river, and also for enlarging the harbour by a new canal through Cannon's Marsh. But nothing was done. The Bristol vessels continued to lie upon the mud and get "hogged;" and a considerable time elapsed before the commercial interests became alive to the necessity of improving the conveniences of the harbour. This was eventually accomplished by William Jessop, a pupil of Smeaton's, but not until Liverpool had taken the lead of Bristol among the western ports, because of the convenient accommodation which it had provided for shipping, as well as on account of its more ready connection with the best markets.

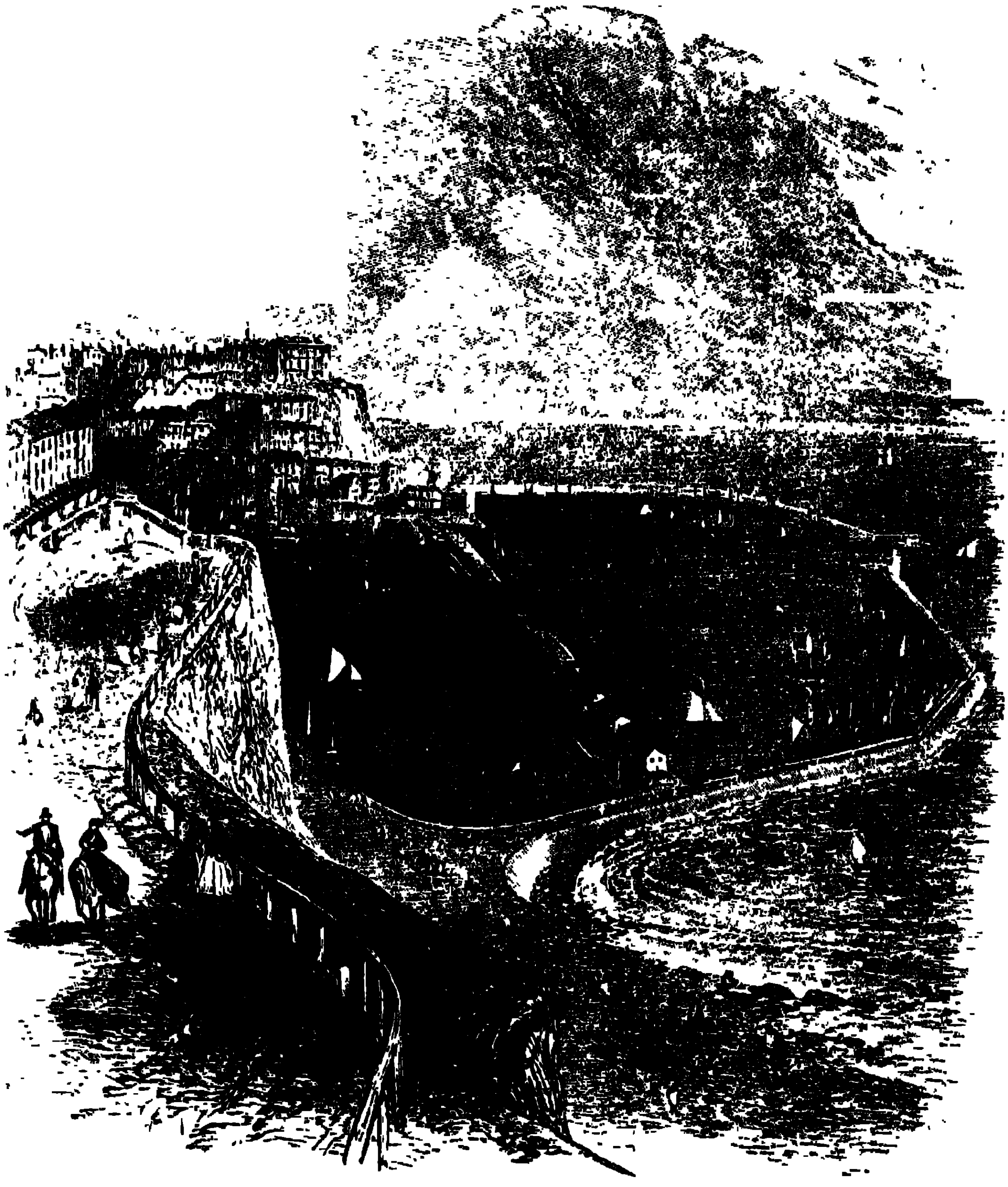
The principal harbour works actually executed by Mr. Smeaton were those of Ramsgate. The proximity of this harbour to the Downs and the mouth of the Thames rendered it of considerable importance; and its improvement for purposes of trade, as well as for the shelter of distressed vessels in stormy weather, was long regarded as a matter of almost national importance. The neighbourhood of Sandwich was first proposed for a harbour of refuge as early as the reign of Queen Elizabeth, and the subject was revived in succeeding reigns. In 1737, Labelye, the architect of Westminster Bridge, was called upon to investigate the subject; and ten years later, a Committee of the House of Commons, after taking full evidence and obtaining every information, reported that "a safe and commodious harbour may be made into the Downs near Sandown Castle, fit for the reception and security of large merchantmen and ships of war, which would also be of great advantage to the naval power of Great Britain."

The estimated cost of the proposed harbour was, however, considered too formidable, although it was under half a million; and the project lay dormant until a violent storm occurred in the Downs in 1748, by which a great number of ships were forced from their anchors and driven on shore. Several vessels, however, found safety in the little haven at Ramsgate, which was then used only by fishermen, the whole extent of its harbour accommodation consisting merely of a rough rubble pier.



Map of Ramsgate and Harbour. [Ordnance Survey.]

This circumstance seems to have had the effect of directing attention to Ramsgate as the proper place for a harbour of refuge for vessels in distress from bad weather in the Downs. The Legislature was petitioned on the subject, and an Act was passed in 1749, enabling a harbour to be



Ramsgate Harbour. [By Percival Skelton, after his original Drawing.]

constructed at Ramsgate. A large number of plans was sent in, from which the Trustees made selections, adopting the east stone pier of one amateur, and the west wooden one of another. The plan of the east pier was made by one of the Trustees, and that of the west pier by a captain resident at Margate. Whilst the works were in progress, the Harbour Trustees proposed to reduce its area, and consequently the extent of accommodation for shipping.

On this decision becoming known, the shipping interest memorialised Parliament on the subject, in 1755, and an inspection of the works was ordered, during which they were entirely suspended, and remained in that state during the next six years. Differences arose between the officers appointed by the Government and the Harbour Trustees as to the plan most proper to be carried out. At length the Trustees gave way, and that part of the works which had been executed with a view to the contraction of the harbour was taken up, and the piers proceeded in the direction originally intended. It was, however, a matter of great vexation to observe that even while the construction of the piers was in progress, and especially when they were carried out so far as to bend towards each other, with the object of affording the requisite protection to the shipping within them, large quantities of sand and silt began to collect in the harbour, threatening to choke it up altogether. And this accumulation of silt went on, notwithstanding every effort made to remove it.

At this juncture Mr. Smeaton was, in 1774, called upon to advise the Harbour Board as to the steps most proper to be taken in the matter. After a careful examination, he ascertained that no less than 268,700 cubic yards of sand and mud had already silted up, every tide bringing in a fresh quantity and depositing it in the still water of the harbour, which was without any natural scour to carry it away. He accordingly recommended a plan for accomplishing this object by means of sluices, supplied by an artificial backwater. He pointed out that Ramsgate Harbour, having a sound bottom of chalk, was well adapted for the execution of this scheme, and that provided the silt could be thus scoured out, the tide, running cross-ways upon the harbour's mouth, would easily carry it away. Mr. Smeaton accordingly accompanied his report with a plan showing the details of his design. He proposed to enclose two spaces of four acres each, and to provide them with nine draw-gates: four upon the westernmost, and five upon the easternmost basin, the whole being pointed in three different directions: two towards the curve of the western pier, four towards the harbour's mouth, and three towards the curve in the eastern pier. To give the sluices all possible effect, he proposed to construct a caisson, shaped something like the pier of a bridge, which, being floated to its place, and then sunk, might be used to direct the current to the right hand or the left according to circumstances. Several experiments having been made with a lighter filled with water and scuttled when the tide was out, the efficacy of the scouring process was thus ascertained. It was finally resolved to adopt the general features of Smeaton's plan, though it was not carried out in the exact manner designed by him. But it was shortly found that the process of sluicing endangered the foundations of the piers.

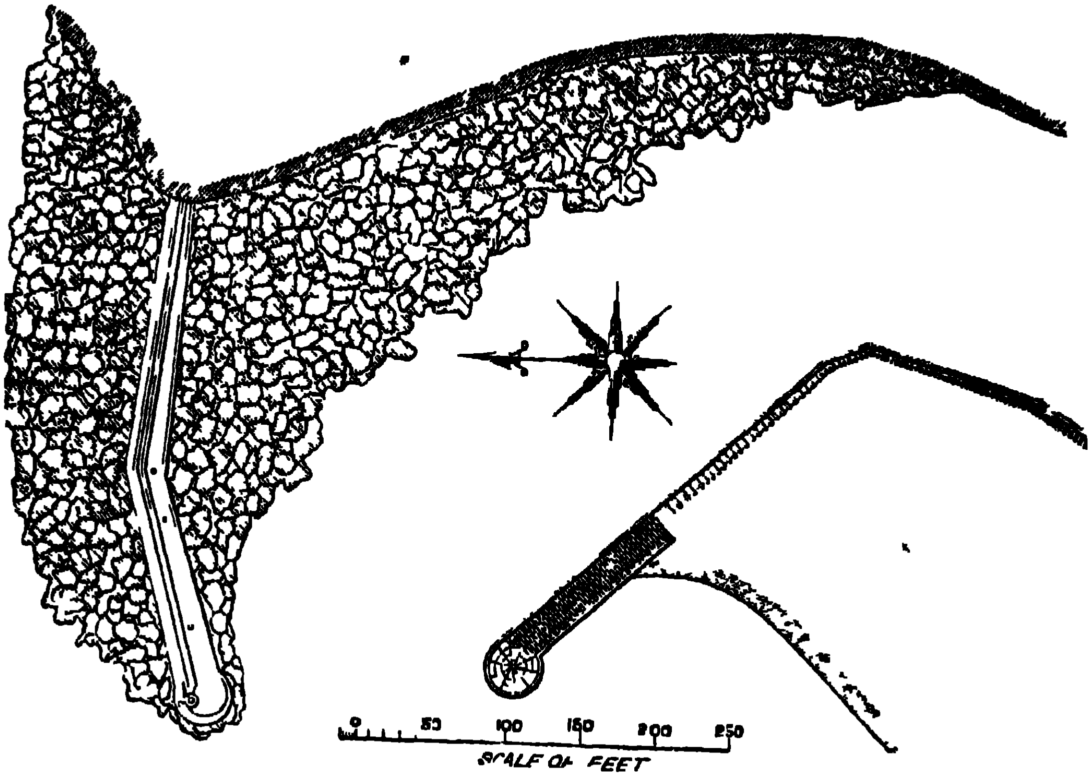
Our engineer was accordingly again called in, when he recommended further improvements, including a new dock, the first stone of which was laid in July 1784. In the course of the excavations numerous springs were tapped, which broke through the pavement with which the dock had been laid, and Portland blocks were then substituted; but this not proving effectual, the engineer was again sent for, and from that time forward the execution of the further works in connection with the harbour was placed entirely in his hands. The dock was rebuilt, a timber floor laid in the most complete manner throughout, and an additional thickness given to the walls. The east pier was rebuilt of stone, and carried out into deep water to a farther extent of 350 feet.

In carrying out the elongated pier, Smeaton first employed the diving-bell in building the foundations, making use of a square wooden chest, partly of iron, weighing about half a ton. It was 4 feet 6 inches in height and length, and 3 feet wide, affording room for two men to work in it; and they were provided with a constant supply of fresh air by means of a forcing pump placed in a boat which floated above them.

The works, when finished, were found to answer remarkably well. The harbour included an area of forty-two acres, the piers extending 1310 feet into the sea, the opening between the pier-heads being 200 feet in width. The inner basin is used as a wet dock, and also contains a dry dock for the repair of ships. With its many defects, and its limited depth, the harbour is nevertheless the best upon that coast, and in stormy weather affords a refuge to vessels of considerable draught of water that run for protection there at high tide.

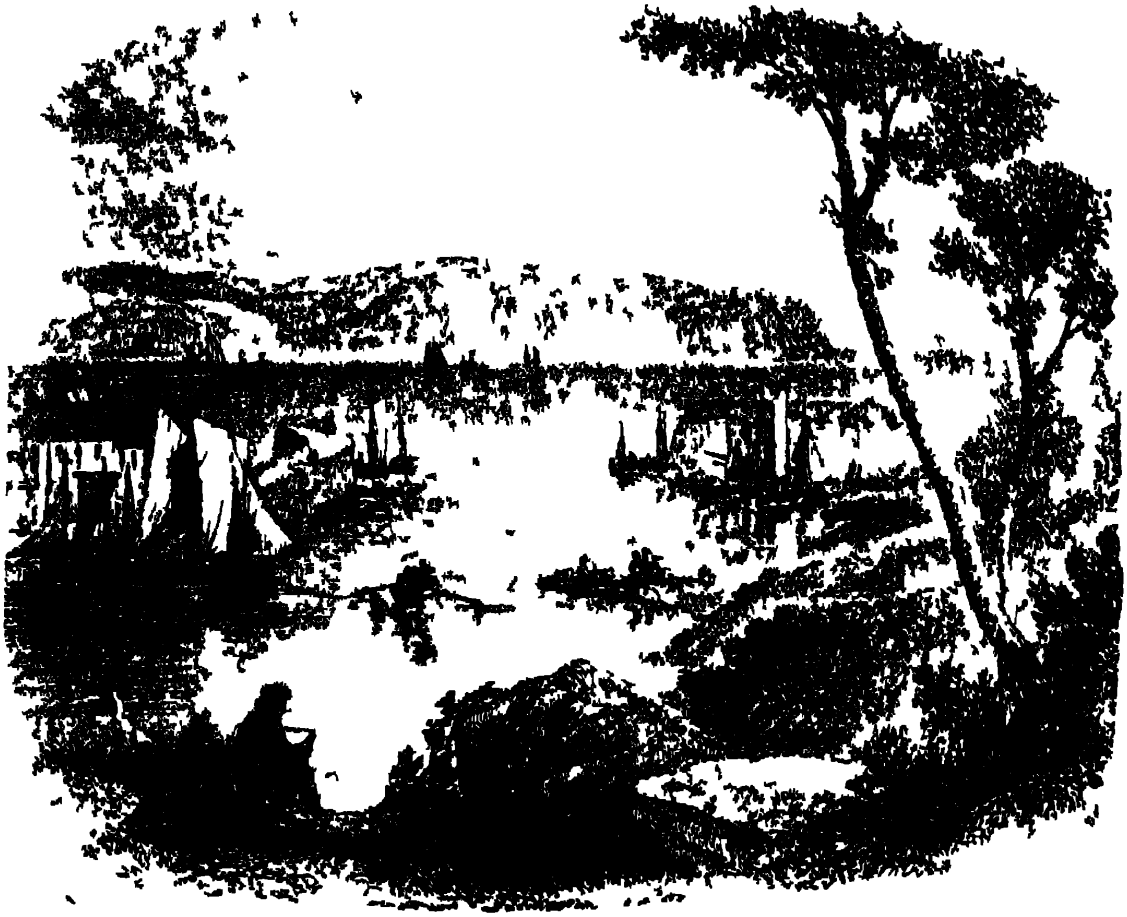
Besides the harbours constructed or improved by him at different points of the English coast, Smeaton was frequently employed during his Scotch journeys in inspecting the northern harbours and advising the local authorities as to the means of increasing their security and accommodation. Thus the harbour at Aberdeen was altered after his plans in 1770, and a greater depth of water was secured over the bar and in the channel of the river Dee, by the erection of the old North Pier, and other additions which served their purpose, until the enlarged trade of the town required the more ample accommodation hereafter to be described in the Life of Telford. He also inspected and reported on the harbours of Dundee and Dunbar, then of very limited capacity, and several improvements of a minor character were carried out by his advice. The small harbours of Portpatrick on the west, and Eyemouth on the east coast, were constructed after his plans; and in his report on Scarborough Pier, dated August 1781, he states that they had "given entire satisfaction."

Both of these harbours were in a great measure formed by nature, and the improvement of them demanded comparatively small skill on the part of the engineer. He had merely to follow the direction of the rocks, which provided a natural foundation for his piers at both places. Of his little harbour at Eyemouth he was somewhat proud, as it was one of the first he constructed, and it very effectually answered its purpose at a comparatively small outlay of money. It lies at the corner of a bay, opposite St. Abb's Head on the coast of Berwickshire, and is almost landlocked, excepting from the north. Smeaton accordingly carried his north pier into deep water for the purpose of protecting the harbour's mouth from that quarter, as well as enlarging the accommodation of the haven. The harbour was thus rendered perfectly safe in all winds, and proved of great convenience and safety to the fishing-craft that chiefly frequent it.



Plan of Eyemouth Harbour

It would occupy too much space to refer in detail to the various other public works on which Mr. Smeaton was employed in the course of his professional career. There was scarcely a crazy old bridge in the kingdom on which he was not called upon to report. He was consulted respecting canal projects almost until the close of his life; amongst others on the improvement of the Birmingham Canal, the Ure Canal, the Dublin Grand Canal, and various



Plymouth Harbour. [By Percival Skelton.]

other schemes of the same sort. He was the principal authority on lighthouses, and amongst others he erected two on Spurn Point at the entrance to the Humber between the years 1771-6, which had before been lighted by coal fires. The Government consulted him respecting their dockyards at Plymouth and Portsmouth. Water companies consulted him as to water supply, and landowners and coalowners as to the best method of draining their lands or working their mines. He was called upon to design many weirs, sluices, and dams, and his dam on the Coquet, north of Newcastle, was considered one of the most complete works of its kind.

He was ready to supply a design of any new machine, from a ship's pump or a fire-bucket to a turning-lathe or a steam-engine. His machinery was neatly designed, and he was very particular as to its careful execution and finish. The water-pumping engine which he erected for Lord Irwin, at Temple Newsam, near his own house at Austhorpe, to pump the water for the supply of the mansion, is an admirable piece of workmanship, and continues at this day in good working condition.

His advice was especially sought on subjects connected with mill-work, water-pumping, and engineering of every description—flour-mills and powder-mills, wind-mills and water-mills, fulling-mills and flint-mills, blade-mills and forge hammer mills. From a list left by him in his own handwriting, it appears that he designed and erected forty-three water-mills of various kinds, besides numerous wind-mills. Water-power was then used for nearly all purposes for which steam is now applied—such as grinding flour, sawing wood, boring and hammering iron, fulling cloth, rolling copper, and driving all kinds of machinery.

Smeaton also bestowed much patient study on the development of the infant powers of the steam-engine. In order to investigate the subject by experiment, he expressly erected a model engine, after Newcomen's principle, at his house at Austhorpe; and by improving it in all its arrangements, he succeeded in rendering it as complete as it was possible to make it—his Chacewater engine of 150-horse power being regarded as the finest and most powerful of its kind which had until then been erected.

Mr. Farey says of his labours in this respect:—"Although Mr. Smeaton did not add anything to the invention of Newcomen, he established just proportions for engines of all sizes; and the performance of the engines he constructed' greatly exceeded the common sort, as they had been usually made before his time." *

In this field of invention, however, he found himself distanced by Watt, the superior merit of whose condensing-engine—notwithstanding the time and labour Smeaton had bestowed on the improvement of Newcomen's—he generously acknowledged; frankly admitting, after he had inspected Watt's invention, that "the old engine, even when made to do its best, was now driven from every place where fuel could be considered of any value."

The fame of Smeaton, therefore, does not rest upon his improvements in this machine, though what he accomplished in bringing out the full powers of Newcomen's engine cannot fail to elicit the admiration of the practical mechanic.

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* Farey's 'Treatise on the Steam-engine,' p 134

Smeaton's House at Austhorpe
[By Percival Skelton, after an original Drawing by J. Sutcliffe, Leeds.]

CHAPTER VI.

SMEATON'S PRIVATE LIFE—DEATH AND CHARACTER.

WHILST Mr. Smeaton was thus extensively employed as an engineer throughout the three kingdoms, his home continued to be at Austhorpe, near Leeds, where he had been born. The mechanical experiments of his boyhood had been conducted there, as well as those of his maturer years. His father had allowed him the privilege of a workshop in an outhouse, which he long continued to occupy; after which, when the house had become his settled home, he erected a shop, study, and observatory, all in one, for his own special use. The building was in the form of a square tower, four storeys high, standing apart from his dwelling, on the opposite side of the yard, as represented on the annexed engraving. The ground-floor contained his forge; the first floor his lathe; the second his models; the third was his drawing-room and study; and the fourth was the attic, which was used as a lumber-room. From the little turreted staircase at the top, a door opened on to the leads. A vane was fixed on the summit, which worked the hands of a dial on the ceiling of Smeaton's drawing-room, so that by raising his head he could at any moment ascertain precisely which way the wind blew.

When he entered his sanctum, strict orders were given that he was not to be disturbed on any account. No one was permitted to ascend the circular staircase which led to his study. When he heard a footstep below, he would call out and inquire what was wanted. His blacksmith, Waddington, was not allowed even to announce himself, but was ordered on all occasions to wait in the lower apartment until Mr. Smeaton came down; and as the smith was equally paid for his time, whether he was sitting there or blowing his forge, it was much the same to him.

When not engaged in drawing plans or writing reports, the engineer's time was principally occupied with astronomical studies and observations. Even in the height of his professional career, and when fully employed, he continued to indulge in this solitary pleasure, and for many years he was a regular contributor of papers on astronomical subjects to the Royal Society.* The instruments with which he was accustomed to illustrate his papers, were of the most beautiful workmanship, all made by his own hands, which had by no means lost their cunning. Indeed, he was nowhere so happy as in his workshop amongst his tools, except it might be at his own fireside, where he was all but worshipped.

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* The following are the papers read by him before the Royal Society, in addition to those previously mentioned:—'Discourse concerning the Menstrual Parallax, arising from the mutual gravitation of the earth and moon, its influence on the observation of the sun and planets, with a method of observing it;' read before the Royal Society May 12th, 1768.—'Description of a new method of observing the heavenly bodies out of the meridian;' read May 16th, 1768.—'Observation of a Solar Eclipse, made at the Observatory at Austhorpe;' read June 8th, 1769.—'A description of a new

His contrivances of tools were endless, and he was perpetually inventing and making new ones. There are large quantities of these interesting relics still in existence in the possession of the son of the blacksmith, who lives in the neighbourhood. When the author lately made inquiry after them, they were found laid in a heap in an open shed, covered with dirt and rust. One article, after having been well scrubbed with a broom, at length displayed the form of a jack-plane, the tool with which Smeaton himself had worked. Picked out from the heap were also found his drill, the bow formed of a thick piece of cane; his trace, his T square, his augurs, his gouges, and his engraving tools. There was no end of curiously arranged dividers; pulleys in large numbers, and of various sizes; cog-wheels; brass hemispheres; and all manner of measured, drilled, framed, and jointed brass-work.

His lathe is still in the possession of Mr. Mathers,

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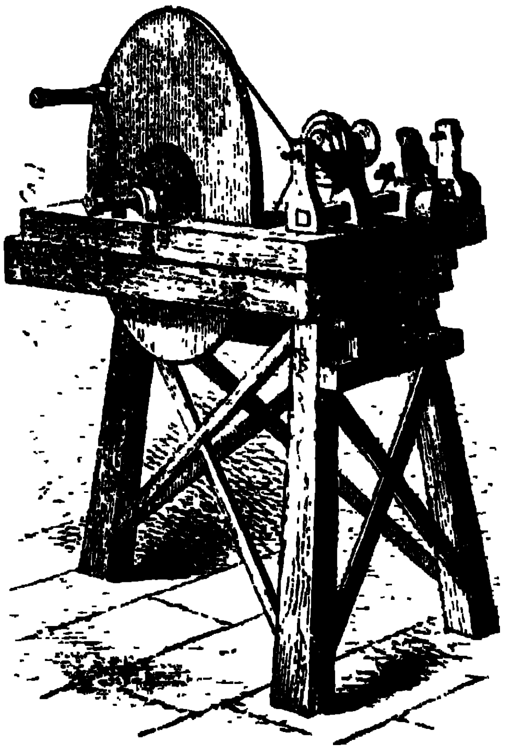
hygrometer, by Mr. J. Smeaton, F.R.S.;' read March 21st, 1771.—'An experimental examination of the quantity and proportion of mechanic power necessary to be employed in giving different degrees of velocity to heavy bodies from a state of rest;' read April 25th, 1776.—'New fundamental experiments on the collision of bodies;' read April 18th, 1782.—'Observations on the graduation of astronomical instruments;' read November 17th, 1785.—'Account of an observation of the right ascension and declination of Mercury out of the meridian, near his greatest elongation, September, 1786, made by Mr. John Smeaton; with an equatorial micrometer of his own invention and workmanship, accompanied with an investigation of a method of allowing for refraction in such kind of observations;' read June 27th, 1787.—'Description of an improvement in the application of the quadrant of altitude to a celestial globe, for the resolution of problems dependent on azimuth and altitude;' read November 20th, 1788.—'Description of a new hygrometer;' read before the same Society.

engineer, Hunslet;* but many of the other interesting remains of the great engineer are equally worthy of preservation. To mechanics, there is a meaning in every one of them. They do not resemble existing tools, but you can at once observe that each was made for a certain reason; and one can almost detect what the contriver was thinking about, when he made them so different from those we are now accustomed to see.



Smeaton's Lathe.

Even in the most trifling matters,—such as the kind of wood or metal used, the direction of the fibre of the wood, and such like,—each detail has been carefully studied. Much even of the household furniture seems to have been employed in their fabrication, possibly to the occasional amazement of the ladies in Smeaton's house over the way. We are informed that so much "rubbish," as it was termed, was found in that square tower at his death, that a fire was kindled in the yard, and a vast quantity of papers, letters, books, plans, tools, and scraps of all kinds, were remorselessly burnt.

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* The lathe stands on three legs, which are fastened together in such a way that they, as well as the rest of the framework, are still as firm as if they had been only just made, and yet the machine has been in use ever since Smeaton made it. The fly-wheel is of dark walnut-wood, and slightly inclines from the perpendicular, by which the driving-cord is allowed to be crossed and to play with a greater amount of friction on the other wheels. The metal-work is of brass, iron, and steel, all nicely finished; and the whole is very compact, curious, and thoroughly Smeaton-like.

We have said that Smeaton was a born mechanic; and a mechanic he remained to the last. He contrived and constructed from pure love of invention. Among the traditions which survive about him at Whitkirk, is this, that when new gates were erected at the entrances to Temple Newsam Park, near his house at Austhorpe, he volunteered to supply the designs, and they were made and hung after his plans. He also contrived a threshing-machine; the grain being rubbed out of the ear by means of a number of nails fixed in a continuous wooden belt. The people of the neighbourhood, however, think that his most wonderful work is the ingenious hydraulic ram, contrived by himself, by means of which the water is still raised in the grounds of Temple Newsam.

His pursuits in his workshop, and at his desk, were varied by visits to his blacksmith's shop. One of his principal objects, on such occasions, was to experiment upon a boiler the lower part copper and the upper part lead—which he had fitted up in an adjoining building, for the purpose of ascertaining the evaporative power of different kinds of fuel, and other points connected with the then little understood question of steam power. He was on very familiar terms with the smith, and if he thought him not very handy about a piece of work he was engaged upon, he would take the tools himself and point out how it should be done. One of the maxims which he frequently quoted to his smith was, "Never let a file come where a hammer can go."

When getting work done in other parts of the country, if a workman appeared to him unhandy, or at a loss how to proceed, he would take up the tools and finish the piece of work himself. "You know, Sir," observed the son of Smeaton's blacksmith, still living, "workmen didn't know much about drawings at that time a-day, and so when Mr. Smeaton wanted any queer-fangled thing making, he'd cut one piece out o' wood, and say to my father, 'Now, lad, go make me this.' And so on for ever so many pieces; and then he'd stick all those pieces o' wood together, and say, 'Now, lad, thou knows how thou made each part, go mak it now all in a piece.' And I've heard my father say, 'at he's often been cap't to know how he could tell so soon when owt ailed it, for before ever he set his foot at t' bottom of his twisting steps, or before my father could get sight of his face, if t' iron had been wrong, theard been an angry word o' some sort, but t' varry next words were, 'Why, my lad, thou s'ud a' made it so and so: now go mak another.'"

Mr. Smeaton's professional engagements called him frequently to London, where he spent part of every year, occupying chambers in Gray's Inn. He had joined his friend Mr. Holmes, in 1771, in the proprietorship of the works for supplying Deptford and Greenwich with water, and he devoted considerable attention to the requisite mechanical arrangements. On the occasion of his visits to London, it was a source of great pleasure to him to attend the meetings of the Royal Society, as well as to cultivate a friendship with the distinguished members of the Royal Society Club.[*]

He was a frequent witness before Committees of both Houses of Parliament[†] in support of Bills for authorising the construction of bridges, canals, and water-works; and was accustomed on such occasions to give his evidence in a modest, simple, and straightforward manner, such as is calculated to win confidence and respect, far more than that glib and unscrupulous style which has since become the fashion. Moreover, he was known to be a most conscientious man, and that he would not express an opinion on any subject until he had thoroughly mastered it.

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[*] James Watt writes:—"When I was in London in 1785, I was received very kindly by Mr. Cavendish and Dr. Blagden, and my old friend Smeaton, who has recovered his health, and seems hearty; dined at a turtle feast with them, and the Select Club of the Royal Society; and never was turtle eaten with greater sobriety and temperance, or more good fellowship." ('Rise and Progress of the Royal Society Club.' 1860.)

[†] It is stated in a recent work, edited by the learned Recorder of Birmingham, M. D. Hill, Esq., entitled 'Our Exemplars,' that "Smeaton was for several years an active member of Parliament, and many useful bills are the result of his exertions. . . . His speeches were always heard with attention, and carried conviction to the minds of his auditors." This must, however, be a mistake, as Smeaton was never in Parliament, except for the purpose of giving engineering evidence before committees; and, instead of being eloquent, Mr. Playfair says he was very embarrassed even in ordinary conversation.

During the time spent by Mr. Smeaton in town, he was accustomed to meet once a week, on Friday evenings, in a sort of club, a few friends of the same calling,—canal-makers, bridge-builders, and others of the class then beginning to be known by the generic term of Engineers. The place of meeting was the Queen's Head Tavern in Holborn; and after they had come together a few times, the members declared themselves a Society, and kept a register of membership,—free social conversation on matters relating to their business being the object of their meetings. Some personal disagreement, however, occurring, through the offensive behaviour of one of the members, Mr. Smeaton withdrew from the club, which came to an end in 1792. Mr. Holmes says of him, that though of a very kindly and genial nature, he was occasionally abrupt, and, to those who did not know him, apparently harsh in his manner; and that he would sometimes break out hastily when anything was said that did not tally with his ideas; not being disposed to yield upon any point on which he argued, until his mind was convinced by sound reasoning.*

Mr. Smeaton earned a fair income by the practice of his profession; but he was no worshipper of money. Though he had an insatiable appetite for work, and was occupied in useful pursuits from youth to old age, his pecuniary wants were very moderate. Those were not the days when great fortunes were made by engineering;

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* Mr. Holmes's 'Short Narrative,' p. 15.

and Mr. Smeaton was satisfied to be paid two guineas for a full day's work. Moreover, he refused new engagements, rather than imperfectly perform what he had already undertaken.

He also limited his professional employment, that he might be enabled to devote a certain portion of his time to self-improvement and scientific investigation. The maxim which governed his life was, that "the abilities of the individual were a debt due to the common stock of public well-being." This high-minded principle, on which he faithfully acted, kept him free from sordid self-aggrandisement, and he had no difficulty in resisting the most tempting offers which were made to attract him from his settled course.

When pressed on one occasion to undertake some new business, and when the prospect of a lucrative recompense was held out to him, he called in the old woman who took charge of his chambers at Gray's Inn, and pointing to her, said, "Her attendance suffices for all my wants." When urgently called by duty, he was ready with his help; but he would not be bought.

The Princess Dashkoff once urged him to go to Russia in order to enter the service of the Empress; holding out to him very tempting promises of reward. He politely refused: no money would induce him to leave his home, his friends, and his pursuits in England, and, though not rich, he had enough and to spare. "Sir," exclaimed the Princess, unable to withhold her admiration, "I honour you! You may have your equal in abilities perhaps; but in character you stand alone. The English minister, Sir Robert Walpole was mistaken, and my Sovereign has the misfortune to find one Man who has *not* his price."*

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* Letter written by Mrs Dixon, daughter of the engineer, to the Committee of Civil Engineers, dated 30th October, 1797 relative to the life and character of her deceased father. (Smeaton's 'Reports,' i. 28.)

Influenced by the same spirit, Mr. Smeaton, towards the close of his life, believing that he should be rendering a service to his country by publishing an account of the various works in which he had been engaged as an engineer, avoided as much business as he consistently could, in order to devote himself to that work; and he eventually determined to retire altogether from the profession.*

The only portion of his works that he lived to describe in words, was his 'Narrative of the Construction of the Eddystone Lighthouse.' Indeed, he states that he found the task of describing this work even more difficult than that of erecting it; and he seems to have become inordinately impressed with a sense of the importance of literary composition. He very naively observes in the Preface: "I am convinced that to write a book tolerably well is not a light or an easy matter; for, as I have proceeded in this work, I have been less and less satisfied with the execution. In truth, I have found much more difficulty in writing than I did in building, as well as a greater length of time and application of mind to be employed. I am indeed now older by thirty-five years than I was when I first entered on that enterprise, and therefore my faculties are less active and vigorous; but when I consider that I have been employed full seven years, at every opportunity, in forwarding this book, having all the original draughts and materials to go upon, and that the production of these original materials as well as the building itself were despatched in half that time, I am almost tempted to subscribe to the sentiment adopted by Mr. Pope, that 'Nature's chief masterpiece is writing well.' It is true that I have not been bred to literature, but it is equally true that I was no more bred to mechanics: we must therefore conclude that the same mind has in reality a much greater facility in some subjects than in others."

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* A year before his death, Mr. Smeaton formally took leave of the profession in the following circular:—"Mr. Smeaton begs leave to inform his friends and the public in general, that having applied himself for a great number of years to the business of a Civil Engineer, his wishes are now to dedicate the chief part of his remaining Time to the Description of the several Works performed under his Direction. The Account he lately published of the Building of Eddystone Lighthouse of Stone has been so favourably received, that he is persuaded he cannot be of more service to the Public, or show a greater Sense of his Gratitude, than to continue to employ himself in the way now specified. He therefore flatters himself, that in not yielding to the many applications made to him lately for further Undertakings, but confining himself in future to the Objects above mentioned, and to such occasional Consultations as will not take up much Time, he shall not incur the Disapprobation of his Friends.
"Gray's Inn, 6th October, 1791."

Smeaton's story of the Eddystone Lighthouse is, however, told in a very effective manner. It possesses an interest almost dramatic, exhibiting a contest between the strong, skilled, and determined man, and the tremendous forces of nature. It is truly observed by the late Lord Ellesmere, in his 'Essays on Engineering,' that bloody battles have been won, and campaigns conducted to a successful issue, with less of personal exposure to physical danger on the part of the commander in chief, than was constantly encountered by Smeaton during the greater part of those years in which the lighthouse was in course of erection. In all works of danger he himself led the way—was the first to spring upon the rock and the last to leave it; and by his own example he inspired with courage the humble workmen engaged in carrying out his plans, and who, like himself, were unaccustomed to the special terrors of the scene.

The portrait prefixed to this volume gives a good representation of Mr. Smeaton's countenance, the expression of which was gentle, yet shrewd. In person he was of a middle stature, broad and strong made, and possessed originally of a vigorous constitution. In his manners he was simple, plain, and unassuming. He had the bluntness and straightforwardness of speech which usually mark the north-countryman, and never acquired that suavity and polish which are more common amongst educated men in our southern districts. He spoke in the dialect of his native county, and was not ashamed to admit it.* Yet he mixed in good society when in town, though his diffidence, as well as his reluctance to bestow too much time on social enjoyment, caused him to contract his circle as his professional engagements increased.

His daughter has related the anecdote of his meeting, on one occasion, with the Duke and Duchess of Queensberry, which led to a pleasant intercourse with that family. Mr. Smeaton was walking with his wife in Ranelagh Gardens—the fashionable place of resort at that time—when he observed an elderly lady and gentleman fix their marked attention upon him. At length they came up, and the lady, who proved to be the eccentric Duchess of Queensberry, said to Mr. Smeaton, "Sir, I do not know who you are or what you are; but so strongly do you resemble my poor dear Gay (the poet) that we *must* be acquainted. You shall go home and sup with us; and if the minds of the two men accord, as do the countenances, you will find two cheerful old folks, who can love you well; and I think (or you are a hypocrite) you can as well deserve it."

Mr. Smeaton and his wife accepted the invitation, and it proved the commencement of one of his most pleasant London friendships. It happened that the Duke and Duchess had a great love of card-playing, which Smeaton detested. But his good nature would not permit him to hold aloof when asked to take a hand. He played, however, like a boy, his attention never following the game. On one occasion, when it was Pope Joan, and the stake in "Pope" had accumulated to a considerable sum, it became Mr. Smeaton's turn by the deal to double it. of his cards, he took up a scrap of paper, made some calculations on it, and laid it on the table. The Duchess eagerly asked what it was. He replied, "Your Grace will recollect that the field in which my house at Austhorpe stands may be about five acres, three roods, and seven perches, which, at thirty years' purchase, will be just my stake; and if your Grace will make a Duke of me, I presume the winner will not dislike my mortgage." The hint thus given in a joke was kindly taken, and from that time they never played but for the merest trifle.

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* In the Preface to his Eddystone Narrative he says —"As I speak and write a provincial language, as I was not bred to letters, I am greatly obliged to my friends in the country for perusing and abundantly correcting my manuscript"

In his own home he was beloved and revered. His wife died in 1784, after which his two daughters kept house for him until his death. The eldest has left on record a charming picture of his domestic character, which we cannot do better than transcribe:—"Though communicative on most subjects," she says, "and stored with ample and liberal observations on others, of himself he never spoke. In nothing does he seem to have stood more single than in being devoid of that egotism which more or less affects the world. It required some address, even in his family, to draw him into conversation directly relating to himself, his pursuits, or his success. Self-opinion, self-interest, and self-indulgence, seemed alike tempered in him by a modesty inseparable from merit—a moderation in pecuniary ambition, a habit of intense application, and a temperance strict beyond the common standard. . . . . Devoted to his family with an affection so lively, a manner at once so cheerful and serene, that it is impossible to say whether the charm of conversation, the simplicity of instruction, or the gentleness with which it was conveyed, most endeared his home—a home in which from infancy we cannot recollect to have seen a trace of dissatisfaction or a word of asperity to any one. Yet with all this he was absolute! And it is for casuistry, or education, or rule, to explain his authority; it was an authority as impossible to dispute as to define."

Mrs. Dixon illustrates the benevolence of her father's character by referring to a painful and trying event in his life. Mr. Smeaton had befriended a young man whom he had employed as a clerk, and he had successfully exerted himself to procure for him a situation of trust and responsibility, at the same time becoming bound for him, jointly with another gentleman, in a considerable sum. The young man fell into bad habits: his expenses outran his income; he committed a forgery to meet the deficiency, and he was detected, apprehended, and given up to justice.

The same post brought Mr. Smeaton the intelligence of the young man's ruin, the claim for the amount of the forfeited bond, and the refusal of the other person to pay the moiety. Mrs. Smeaton's health being delicate at the time, her husband suppressed all appearance of emotion; nor, until all was put in train for settlement, did a word or look betray the exquisite distress which these painful circumstances had caused him. He even exerted himself to save the prisoner's life, in which he eventually succeeded, and he did all that he afterwards could to soothe the remorse of the wretched youth who had betrayed him.*

Of Mr. Smeaton's intellectual powers it would be difficult to speak too highly. James Watt always mentioned him in terms of sincere admiration, speaking of him as "father Smeaton." Writing to Sir Joseph Banks, he said: "In justice to him we should observe that he lived before Rennie, and before there were one-tenth of the artists there are now. *Suum cuique;* his example and precepts have made us all engineers." Even after the great works of the railway era, and the variety of practical ability which they called forth and fostered, Robert Stephenson pronounced Smeaton to be the engineer of the highest intellectual eminence that had yet appeared in England. Speaking of him to the author in 1858, he observed, "Smeaton is the greatest philosopher in our profession, that this country has yet produced. He was indeed a great man, possessing a truly Baconian mind, for he was an incessant experimenter.* The principles of mechanics were never so clearly exhibited as in his writings, more especially with respect to resistance, gravity, and the power of water and wind to turn mills. His mind was as clear as crystal, and his demonstrations will be found mathematically conclusive. To this day there are no writings so valuable as his in the highest walks of scientific engineering; and when young men ask me, as they frequently do, what they should read, I invariably say, 'Go to Smeaton's philosophical papers; read them, master them thoroughly, and nothing will be of greater service to you.' Smeaton was indeed a very great man."

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* The engineer's daughter, who has related these beautiful features in his character, became the wife of Jeremiah Dixon, Esq., at one time mayor of Leeds, afterwards of Fell Foot, Windermere, and an active county magistrate. She possessed much of the force of character and benevolence of disposition which distinguished her father; and was regarded as a woman of great practical ability. She survived her husband many years, and during her lifetime built and endowed a free-school for girls at Staveley, about a mile from her residence, which is now, and has been ever since its establishment, of very great benefit to the population of the neighbourhood. Mrs. Dixon was also an artist of some merit, and painted in oils; the altar-piece and decorated Ten Commandments now in Staveley church being of her execution.

From what we have said, it will be obvious that Smeaton was, throughout his whole career, a most industrious man, indeed, industry was the necessity and habit of his life. His daughter describes him as having been incessantly occupied from six years old to sixty. He was a great economist of time, and laid it out in such a way as to obtain from its use the greatest amount of valuable result. When at home, his forenoons were devoted to writing reports, and to the various business arising out of his professional engagements; and his afternoons were occupied by the pursuits in which he took most pleasure,—working at his forge or in his workshop, making mechanical experiments, or preparing his papers on scientific subjects for the Royal Society.

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* One of Smeaton's rules was, never to trust to deductions drawn from theory in any case where there was an opportunity for actual experiment. "In my own practice," he said, "almost every successive case would have required an independent theory of its own. In my intercourse with mankind I have always found those who would thrust theory into practical matters to be, at bottom, men of no judgment, and pure quacks."

Though naturally possessed of an excellent constitution, and capable of enduring much fatigue, it is most probable that he taxed his brain too much, and "o'er informed his tenement of clay," by his continuous and intense application to study during the long periods of his seclusion at Austhorpe. His robust frame became fragile, and his strength was further impaired by the abstinence which he was subsequently compelled to adopt.* Moreover, it appears that brain disease was hereditary in his family, and he long apprehended the stroke which eventually terminated his life. This only made him the more eager to employ to the most advantage the time which it might yet be permitted him to live; and he dreaded above all things the blight of his mental powers—to use his own words, "lingering over the dregs after the spirit had evaporated" - chiefly as depriving him of the means of doing further good.

The last public measure on which he was professionally engaged in London, was the passing of the Bill through Parliament for the construction of the Birmingham and Worcester Canal. It was very strongly opposed, and its support in Committee cost him much application, thought, and anxiety. His friends saw him visibly breaking down, and apprehended that the powers of his vigorous mind were beginning to fail. The Bill passed by a small majority, and Mr. Smeaton went down to his home at Austhorpe for repose.

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* Since the first edition of this work appeared, a correspondent has sent us a copy of a letter written by Mr. Smeaton, on the 4th of August, 1792, alluding to the extraordinary disease under which he laboured at that time. Mr. Smeaton says:—"I am obliged by your inquiries after my health, but unless the dreadful disorder in my stomach can be effectually removed, which consists in an over quick digestion, and is medically called the *Fames Canina*, I believe my mental faculties will be of little further use. The length of time I was kept in tow by the Ramsgate Bill last spring, so thoroughly confirmed the disorder, that all the relief I have ever since found, by riding on horseback in my native air, seems to make but very slow progress towards a cure. . . . P.S.—You will scarcely be able to conceive what a task it has been to get this letter written."

Shortly after, when walking in his garden, he was struck by paralysis. Happily his faculties returned to him, and he expressed his thankfulness to the Almighty that his intellect had been spared. He was very resigned and cheerful, and took pleasure in seeing the usual social occupation of the family going on about him. He would, however, complain of his growing slowness of apprehension and excuse it with a smile, saying, "It could not be otherwise: the shadow must lengthen as the sun goes down." Some phenomena relating to the moon formed the subject of conversation one evening, when its fulness shone very bright into his room. Fixing his eyes upon it, he said, "How often have I looked up to it with inquiry and wonder, and thought of the period when I shall have the vast and privileged views of an hereafter, and all will be comprehension and pleasure!"

He even continued to dictate letters to his friends; and in one of these, addressed to Mr. Holmes, after describing his health and feelings, he said: "In consequence of the foregoing, I conclude myself nine-tenths dead, and the greatest favour the Almighty can do me (as I think) will be to complete the other part; but as it is likely to be a lingering illness, it is only in His power to say when that is likely to happen." His suffering, however, did not last long; and after the lapse of about a month from the writing of this letter, the engineer's spirit found repose.

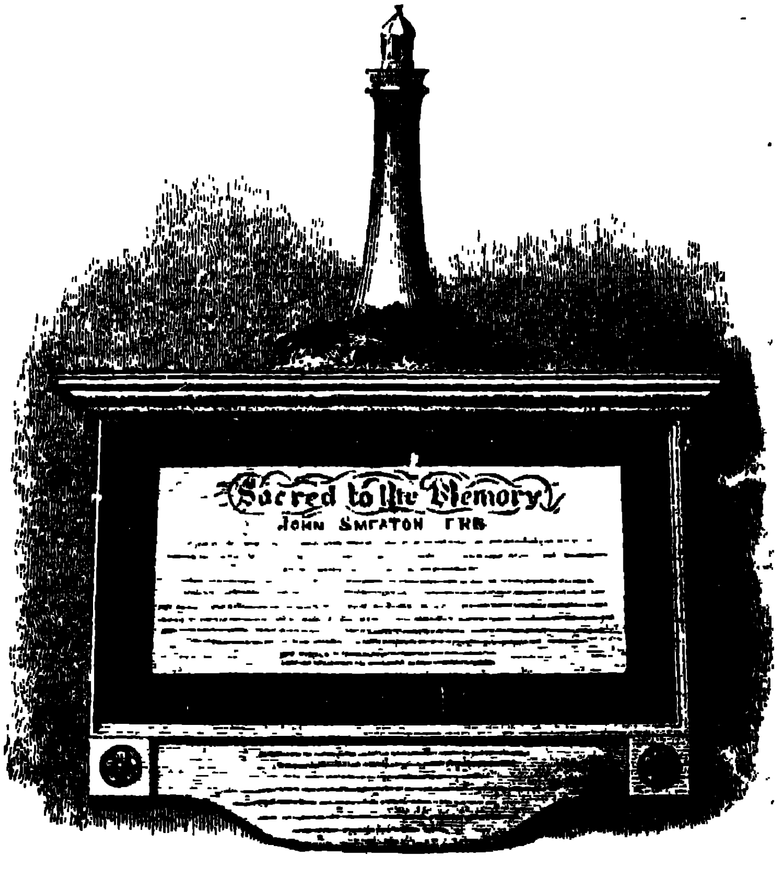
He died on the 28th of October, 1792, in the 68th year of his age; and was buried with his forefathers in the old parish church of Whitkirk, where a tablet with the following inscription was erected to his memory:—

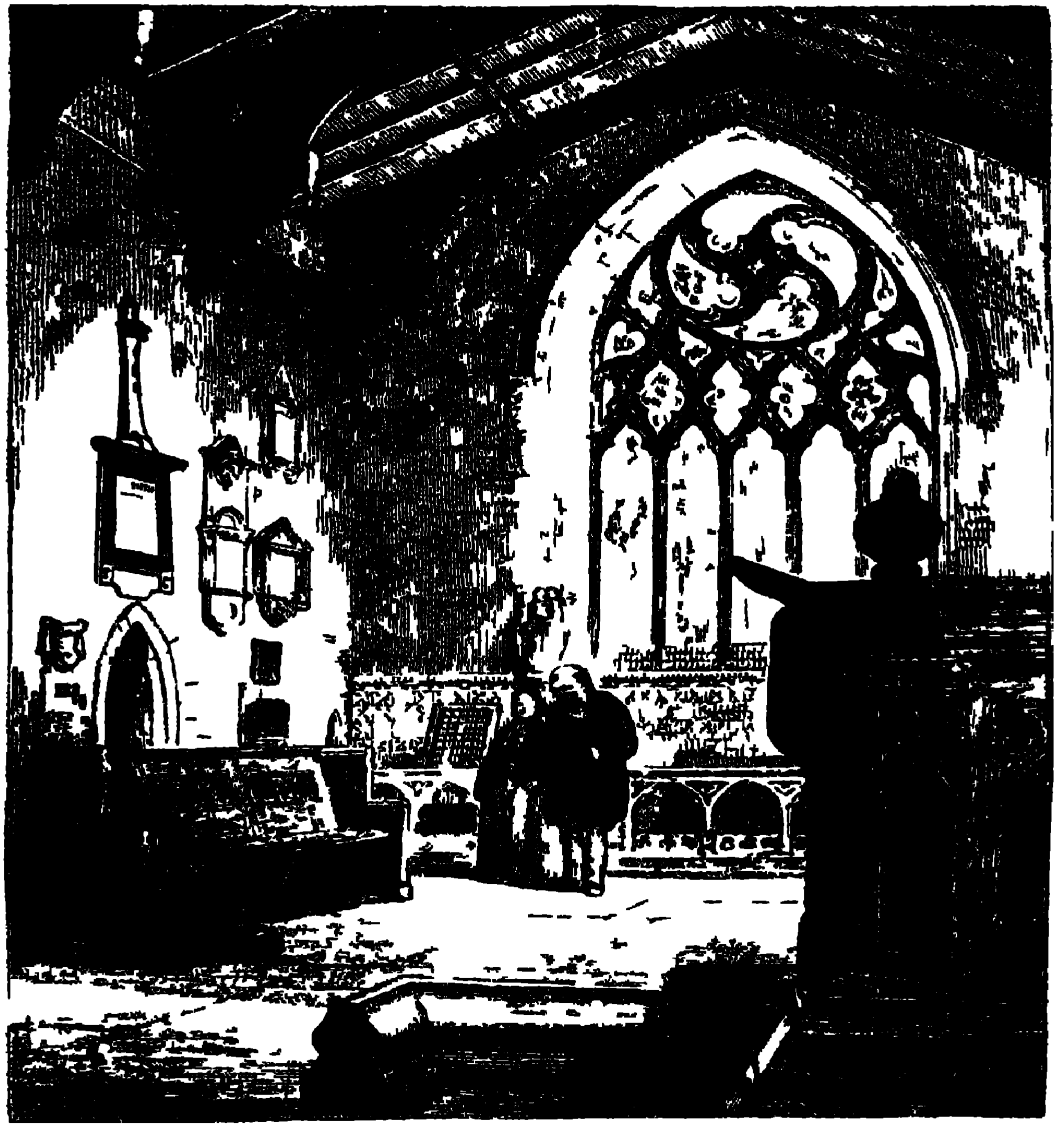
SACRED TO THE MEMORY
OF JOHN SMEATON, F.R.S.

A Man whom God had endowed with the most extraordinary abilities,
which he indefatigably exerted for the benefit of Mankind in
works of Science and Philosophical research:
More especially as an Engineer and Mechanic. His principal work, the Eddystone Lighthouse, erected on a rock in the open sea, (where one had been washed away by the violence of a storm, and another had been consumed by the rage of fire,) secure in its own stability and the wise precautions for its safety, seems not unlikely to convey to distant ages, as it does to every Nation of the Globe, the Name of its constructor.

He was born at Austhorpe, June 8, 1724.
And departed this Life October 28, 1792.

Also Sacred to the Memory of
ANN, the wife of the said JOHN SMEATON, F.R.S.,
Who died January 17th, 1784.
Their two surviving Daughters,
Duly imprest with sentiments of Love and Respect
For the kindest and tenderest of Parents,
Pay this tribute to their Memory.





Smeaton's Burial place in Whitkirk Church

[By G. Cattermole, after an original Sketch by T. Sutcliffe, Leeds.]

[illegible] OF JOHN RENNIE.

CHAPTER I.

RENNIE'S BOYHOOD AND EDUCATION.

[illegible] RENNIE, the architect of the three great London [illegible], the engineer of the Plymouth Breakwater, of the [illegible] London Docks, and other works of great national [illegible], was born at the farm-steading of Phantassie, [illegible] Lothian, on the 7th of June, 1761. His father,

Rennie's Native District [Ordnance Survey.]

[illegible], was the owner of the patrimonial estate, [illegible] midway between Haddington and Dunbar, [illegible] the gently-sloping hills which rise from it [illegible] south,—the village of East Linton lying close [illegible] the farther bank of the little river Tyne.

The only post road from London to Scotland passed close in front of the house at Phantassie in which John Rennie was born. It passed westward over Pencrake, and followed the ridge of the Garleton Hills towards Edinburgh. The old travellers had no aversion to hill tops, rather preferring them because the ground was firmer to tread on, and they could better see about them. This line of high road avoided the county town, which, lying in a hollow, was unapproachable across the low grounds in wet weather; and, of all things, swamps and quagmires were most to be dreaded. A portion of the old post-road was visible until within the last few years, upon the high ground about a mile to the north of Haddington. In some places it was very narrow and deep, not unlike an old broad ditch, much waterworn, and strewn with loose stones. Along this line of way Sir John Cope passed with his army, in 1745, to protect Edinburgh against the Highland rebels; and it is related that, on marching northward to intercept them, he was compelled to halt for several days, waiting for a hundred horse-loads of bread required for the victualling of his army.

In 1750, a project was set on foot for improving the high road through East Lothian, and a Turnpike Act was obtained for the purpose—the first Act of the kind obtained north of the Tweed.* The inhabitants of the town of Haddington complained loudly of the oppression practised on them, by making them pay toll for every bit of coal they burned; though before the road was made, it was a good day's work for a man and horse to fetch a load of "divot" or Turf from Gladsmuir, or of coal from the nearest colliery, only some four miles distant. By the year 1763 this post-road must have been made practicable for wheeled vehicles; for in that year the one stage-coach, which for a time formed the sole communication of the kind between London and all Scotland, began to run; and John Rennie when a boy, was familiar with the sight of the uncouth vehicle lumbering along the road past his door. It "set out" from Edinburgh only once a month, the journey to London occupying from twelve to eighteen days, according to the state of the roads.

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* G. Buchan Hepburn's 'General View of the Agriculture and Economy of East Lothian, 1794.' p. 151.

Dr. Carlyle, in his 'Autobiography,' says, that in 1757, he made an excursion into England, with Sir David Kinloch and some other gentlemen. The baronet and himself rode in a postchaise, "a vehicle which had but recently been brought into Scotland, as our turnpike roads were then in their infancy."* A short time before, when Home, the poet, accompanied by some six or seven Merse ministers, were proceeding to London to get the play of *Douglas* put upon the stage, the entire party rode on horseback. But Home, like an oblivious poet, forgot to provide himself with a pair of leathern bags to put his manuscript in; and he consequently had to balance himself on his horse by putting his tragedy in one pocket of his great coat and his clean shirt and night-cap in the other. "By good luck," says the minister, "the Tweed was not come down, and we crossed it safely at the ford near Norham Castle."†

When Rennie was born, Scotland was a very poor country. Perhaps East Lothian, being a border county, was one of the poorest. It had been constantly overrun and despoiled during the wars with England. Haddington was thrice burnt to the ground. For four centuries, from Edward I. to Oliver Cromwell, the border counties were constantly liable to invasion. The last time East Lothian was spoiled was before the battle of Dunbar. Agriculture had not yet recovered from these frequent attacks. It had become a lost art. But about the middle of last century, agriculture began to show signs of revival. The country as yet consisted mostly of moorland, peat, and bogs. Very little corn was raised; and when the first wheat was grown in a field near Edinburgh, all the country flocked to see it.* James Rennie, the engineer's father, was one of the first to introduce turnips as a regular farmer's crop; for, before his time, neither clover, turnips, nor potatoes were grown in Scotland. Cattle could with difficulty be kept alive; and the people themselves were often on the brink of starvation. They were hopeless, miserable, and without spirit. Some thought that The Union had utterly destroyed Scottish prosperity. There were even Repealers in those days;† but they could not successfully combine. There was very little communication between country and town, or between one town and another; for during the greatest part of the year, the roads were simply impassable. The Darien Expedition had ruined those who had put their money in it; and the people seemed to have no spirit to make any further attempt to prosper. It would appear as if neither skill, money, nor enterprise, remained in the land.

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* Dr. Carlyle, 'Autobiography,' p. 326

† Ibid. 303

Engineering and architecture, like agriculture, seem also to have become lost arts. The few small bridges built at the beginning of the eighteenth century were of a frightful character. They were of a circular form; so

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* There is every reason to believe that at a remote period, Scotland had been well cultivated. The army of Edward I. subsisted on the beans and pease which they found in the field, when besieging Dirleton, East Lothian, in 1298; and from the old chartularies of the Monastic establishments, it is clear that wheat was cultivated to a considerable extent, at the same time. Adda, mother of William the Lion, having founded a nunnery at the Abbey, near Haddington, about the year 1178, endowed it with the rents of certain lands in the neighbourhood. The rents were paid in kind for the maintenance of the nuns, and consisted, amongst other things, of four bolls of wheat and three bolls of oatmeal yearly. And yet, at the beginning of the eighteenth century, the production of wheat in Scotland had been entirely discontinued.

† Among these were Fletcher of Saltoun, the Earl of Wigton, and others. For further remarks as to the decayed state of Scotland at this time, see vol. iii. 'History of Roads,' pp. 48–59.

that, when erected across a stream of say twenty feet in breadth, they rose ten feet in height from the spring of the arch, and descended ten feet on the other side. Crossing a bridge of this sort was like climbing over the roof of a house. The bridge builders of those days had no notion that the segment of a circle, well supported at its springing, was as strong as the full bow. But bridge-building had not always been in this backward state in Scotland. It is probable that the whole country—or at least the Lowland part of it—was in a much more flourishing condition previous to the commencement of the fourteenth century, than it was for some four hundred and fifty years after that time.

The highly improved state of architecture in early times —as is still exhibited in the ruins of the ancient abbeys of Melrose, Elgin, Kilwinning, Aberborthwick, and other religious institutions—lead us to conclude that the other arts and sciences were in a much more forward state than they have been at a more recent period. The same "Brothers of the Bridge" who erected so many fine old bridges across the rivers of England, were equally busy beyond the Tweed, providing those essential means of intercourse for the community. Thus we find Old Bridges early erected across most of the rapid rivers in the Lowlands, especially in those places where the ecclesiastical foundations were the richest; and to this day the magnificent old abbey or cathedral of the neighbourhood—in some corner of which the Presbyterian Church continues to hold its worship—serves to remind one of the contemporaneous origin of both classes of structures.

Thus, as early as the thirteenth century, there was a bridge over the Tay at Perth; bridges over the Esk at Brechin and Marykirk; one over the Dee at Kincardine O'Neil; one at Aberdeen; and one at the mouth of Glenmuick. The fine old bridge over the Dee, at Aberdeen, is still standing: it consists of seven arches, and, as usual, the name of a bishop—Gawin Dunbar—is connected with its erection. There is another old bridge over the Don near the same city, said to have been built by Bishop Cheyne in the time of Robert the Bruce—the famous "Brig of Balgonie," celebrated in Lord Byron's stanzas as "Balgownie Brig's black wa'." It consists of a spacious Gothic arch, resting upon the rock on either side. There was even an old bridge over the rapid Spey at Orkhill.

Then at Glasgow there was a fine bridge over the Clyde, which used, in old times, to be called "the Great Bridge of Glasgow," said to have been built by Bishop Rae in 1345. Though the bridge was only twelve feet wide, it consisted of eight arches; somewhat similar to the ancient fabric which still spans the Forth under the guns of Stirling Castle. This last-mentioned bridge was, until recent times, a structure of great importance, affording almost the only access into the northern parts of Scotland for wheeled carriages.

But the art of bridge-building in Scotland, as in England, seems for a long time to have been almost entirely lost; and until Smeaton was employed to erect the bridges of Coldstream, Perth, and Banff, next to nothing had been done to improve this essential part of the communications of the country. Where attempts were made by local builders to erect such structures, they very rarely stood the force of a winter's, or even a summer's, flood. "I remember," says John Maxwell, "the falling of the Bridge of Buittle, which was built by John Frew in 1722, and fell in the succeeding summer, while I was in Buittle garden seeing my father's servants gathering nettles [for food]." * A similar fate befel the few attempts that were made about the same time to maintain the lines of communication by replacing the old bridges where they had gone to ruin, or substituting new ones in place of fords.

The mechanical arts had also fallen to the very lowest

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* Appendix to 'Picture of Dumfries.' By John MacDiarmid Edinburgh, 1832.

state. All kinds of tools were of the most imperfect description. The implements used in agriculture were extremely rude. They were mostly made by the farmer himself, in the roughest possible style, without the assistance of any mechanic. But a plough, which was regarded as a complicated machine, was reserved for the blacksmith. It was made of young birch trees, and, if the tradesman was expert, it was completed in the course of a winter's evening.* This rude implement scratched, without difficulty, the surface of old crofts, but made sorry work in out-fields, where the sward was tough and stones were large and numerous. Lord Kaimes said of the harrows used in his time, that they were more fitted to raise laughter than to raise mould. Machinery of an improved kind had not yet been introduced into any department of labour. Its first application, as might be expected, was in agriculture,—then the leading, and indeed almost the only, branch of industry in Scotland; and the introduction of machinery will be found both curious and interesting, in its bearing on the subject of our present memoir.

There was one fruitful art, however, remaining in Scotland, which was calculated, more than anything else, to restore the prosperity of the country and that was, the art of teaching. The number of schools throughout the country was considerable, in which the rising generation were well and wisely taught. The "Grammar-schools" in the principal boroughs existed before the Reformation; the parish schools were one of the principal results of the Reformation. The Grammar-schools were founded by benevolent individuals, who vested in the church, or in the burgh corporations, certain property or sums of money, for the purpose of educating the youth of the towns in which they were established. That they existed in the towns when Scotland was a Catholic country, is clear from the fact that John Knox himself was educated at the Grammar

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* 'Farmer's Magazine,' No. xxxiv., p. 199.

School of Haddington, of which town he was a native; and he relates that he there learnt the elements of the Latin language.

But these burgh schools were insufficient for the general education of the people,—who, for the most part, lived in the country, and could scarcely approach the towns during the greater part of the year, by reason of the badness of the roads. Accordingly, one of the first measures which John Knox proposed to the Lords of the Assembly after the Reformation, was the establishment of a school, supported by the heritors, or proprietors of land, in every parish throughout the country. In his first 'Book of Discipline' he explicitly set forth, "That every several Kirke have ane schoolmaister appointed, able to teach grammar and the Latin tongue, if the town be of any reputation;" and, if an upland town, then a reader was to be appointed, or the minister himself must attend to the instruction of the children and youth of the parish. It was also enjoined that "provision be made for the attendance of those that be poore, and not able by themselves or their friends to be sustained at letters;" "for this," it was added, "must be carefully provided, that no father, of what estate or condition that ever he may be, doth use his children at his own fantasie, especially in their youthhead; but all must be compelled to bring up their children in learning and virtue."

This was admirable advice, but it could not be carried into effect for more than a hundred years. The civil wars, the attempts made to impose Episcopacy upon Scotland, and the troubles of the nation down to the Revolution of 1688, prevented the people uniting for the purpose of establishing a school in every parish; but at length, in 1696, the Scottish Parliament was enabled, with the concurrence of William III., to put in force the Act of that year, which is regarded as the charter of the parish-school system of Scotland. It is there ordained, "that there be a school settled and established and a schoolmaster appointed in every parish not already provided, by advice of the heritors and minister of the parish."

In consequence of the operation of this Act, which was gradually carried into effect, the parish schools of Scotland,*—working steadily upon the rising generation, all of whom passed under the hands of the parish teachers,—were training up a population whose education and intelligence were greatly in advance of their material condition; and it is to this circumstance, we apprehend, that the true explanation is to be found of that rapid leap forward which the country now took, dating more particularly from the year 1745. Agriculture was naturally the first branch of industry affected; new crops were introduced, new methods of farming, new machinery for ploughing, harrowing, and reaping the produce of the land. These improvements were followed by like advances in manufactures, commerce, and shipping—by discoveries in invention, of which the Condensing Steam-Engine, discovered by James Watt, was by far the most important.* Indeed, from that period, Scotland has never looked back; but her progress has gone on at a constantly increasing rate —and has issued in results as marvellous as they have probably been unequalled. A century of Work has raised Scotland from the position of one of the poorest and most miserable of countries, to that of one of the best cultivated, most prosperous, and intelligent in Britain.

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* Besides the abundance of schools, and the excellence of the education given, the moderation of the fees charged is worthy of notice. Dr. Guthrie, in his 'Autobiography,' mentions the schools at Brechin, where he was educated some sixty years ago. First he was taught at a private school, of which the late Dr. McCrie was the teacher. "Besides this school," he says, "there were two others in Brechin where Latin and Greek, French and Mathematics, were taught. One of these was endowed from property belonging in Roman Catholic times to the Knights Templars, who had a preceptory there. The other was the parish school. Both were conducted by 'preachers,' or licentiates of the Church of Scotland—university men who had spent at least eight years at college. Both prepared young men for the university, teaching them, besides the more common branches of education, Algebra, Euclid, French, Latin, Greek, and all for five shillings a quarter! That may astonish people now-a-days. But so it was; and the bursaries which a large proportion of these pupils won by open competition at the universities of St. Andrews and Aberdeen, while the means of their support there, proved the goodness of the teaching they got for this small sum. The result of this cheap and efficient education was that the sons of many poor and humble people pulled their way up to honourable positions in life, while the parents had not their self-respect and feelings of independence lowered by owing the superior education of their children to others than themselves." ('Autobiography,' pp. 33–34.)

Farmer Rennie died in the old house at Phantassie in the year 1766, leaving a family of nine children,--four sons and five daughters. George, the eldest, was then seventeen years old. He was discreet, intelligent, and shrewd beyond his years, and from that time forward he managed the farm and acted as head of the family. The year before his father's death he had made a tour through Berwickshire, for the purpose of observing the improved methods of farming introduced by some of the leading gentry of that county, and he returned to Phantassie full of valuable practical information. The agricultural improvements which he was shortly afterwards instrumental in introducing into East Lothian were of a highly important character. His farm came to be regarded as a model, and his reputation as a skilled agriculturist extended far beyond the bounds of his own country, insomuch that he was afterwards resorted to for advice as to farming matters, by distinguished visitors from all parts of Europe.*

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* A writer, in the Scotch *Farmer's Magazine* for 1810, makes the following observations: — "During the last fifty years Scotland has made rapid progress in agriculture, architecture, navigation, and commerce; and it in some she has excelled her neighbours, it may perhaps be ascribed to that wholesome and useful system of parochial education, which was bequeathed to her children by the last Parliament which she ever assembled as an independent kingdom. The elements of learning, consisting of reading, writing, and accounts, though seemingly superficial attainments, have nevertheless, been of immense value to the people. They have enabled them to comprehend, adopt, and improve to the utmost, every new branch of science, as soon as it sprung up in any corner of Europe; and there is no circumstance so peculiar in the possession of a little knowledge, as the desire which it communicates, and the capacity which it bestows, of obtaining still more."

Rennie's Birthplace, Phantassie.
[By E. M. Wimperis, after a Drawing by J. S. Smiles.]

Of the other sons, William, the second, went to sea: he was taken prisoner during the first American war, and was sent to Boston, where he died. The third, James, studied medicine at Edinburgh, and entered the army as an assistant-surgeon. The regiment to which he belonged was shortly after sent to India: he served in the celebrated campaign of General Harris against Tippoo Saib, and was killed while dressing the wound of his commanding officer when under fire at the siege of Seringapatam.

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* Amongst George Rennie's illustrious visitors in his later years was the Grand Duke Nicholas (afterwards Emperor) of Russia, who stayed several nights at Phantassie, and during the time was present at the celebration of a "hind's wedding."

John, the future engineer, was the youngest son, and only five years old at the death of his father. He was accordingly brought up mainly under the direction of his mother,—a woman possessed of many excellent practical qualities, amongst which her strong common sense was not the least valuable.

The boy early displayed his strong inclination for mechanical pursuits. When about six years old, his principal toys were his knife, hammer, chisel, and saw, by means of which he indulged his innate love of construction. He preferred this kind of work to all other amusements, taking but small pleasure in the ordinary sports of boys of his own age. His greatest delight was in frequenting the smith's and carpenter's shops in the neighbouring village of Linton, watching the men use their tools, and trying his own hand when they would let him.

But his favourite resort was Andrew Meikle's millwright's shop, down by the river Tyne, only a few fields off. When he began to go to the parish school, then at Prestonkirk, he had to pass Meikle's shop daily, going and coming; and he either crossed the river by the planks fixed a little below the mill, or by the miller's boat when the waters were high. But the temptations of the millwright's workshop while passing to school in the mornings not unfrequently proved too great for him to resist, and he played truant. He then tried to "make things," and worked at the bench and the forge. The appearance of his fingers and clothes on his return home, revealed the secret of his employment; when a severe interdict was laid against his "idling" away his time at Andrew Meikle's shop.

The millwright, on his part, had taken a strong liking for the boy, whose tastes were so congenial to his own.

Besides, he was somewhat proud of his landlady's son frequenting his house, and was not disposed to discourage his visits. On the contrary, he let him have the run of his workshop, and allowed him to make his miniature water-mills and windmills with tools of his own. The river which flowed in front of Houston Mill was often swollen by spates or floods, which descended from the Lammermoors with great force; and on such occasions young Rennie took pleasure in watching the flow of the waters, and following the floating stacks, fieldgates, and other farm wreck along the stream, down to where the Tyne joined the sea at Tyningham, about four miles below.

Amongst his earliest pieces of workmanship was a fleet of miniature ships. But not finding tools to suit his purposes, he contrived, by working at the forge, to make them for himself; then he constructed his fleet, and launched his ships, to the admiration and astonishment of his playfellows. This was when he was about ten years old. Shortly after, by the advice and assistance of his friend Meikle, who took as much pride in his performances as if they had been his own, Rennie made a model of a windmill, another of a fire engine (or steam-engine), and another of Vellore's pile-engine, displaying a considerable amount of manual dexterity; some of these early efforts of the boy's genius being still preserved.

Though young Rennie thus employed so much of his time on amateur work in the millwright's shop, he was not permitted to neglect his ordinary education at the parish school. That of Prestonkirk was kept by a Mr. Richardson, who taught his pupil well in the ordinary branches of education; but by the time Rennie had reached twelve years of age, he seems almost to have exhausted his master's store of knowledge, and his mother then thought the time had arrived to remove him to a seminary of a higher order.

He was accordingly taken from the parish school, though his friends had not yet made up their minds as to the steps they were to adopt with reference to his further education. The boy, however, found abundant employment for himself with his tools, and went on model-making; but feeling that he was only playing at work, he became restless and impatient, and entreated his mother that he might be allowed to go to Andrew Meikle's to learn to be a millwright.

He was accordingly sent to Meikle's, where he worked for two years, and learnt one of the most valuable parts of education - the use of his hands. He seemed to overflow with energy, and was ready to work at anything—at smith's work, carpenter's work, or millwork; taking most pleasure in the latter, in which he shortly acquired considerable expertness. Having the advantage of books—limited though the literature of mechanism was in those days - he studied the theory as well as the practice of mechanics, and the powers of his mind became strengthened and developed by means of steady application and self-culture.

At the end of two years, his friends determined to send him to the burgh school of Dunbar, one of that valuable class of seminaries directed and maintained by the magistracy, which have been established for the last hundred years and more in nearly every town of any importance in Scotland. Dunbar High School was then a school of considerable celebrity. Mr. Gibson, the mathematical master, was an excellent teacher, full of love and enthusiasm for his profession; and it was principally for the benefit of his discipline and instruction that young Rennie was placed under his charge. On entering this school, he possessed the advantage of being fully impressed with a sense of the practical value of intellectual culture. His two years' service in Meikle's workshop, while it trained his physical powers had also sharpened his appetite for knowledge, and he entered upon his second course of instruction at Dunbar with the disciplined powers of a grown man. He had also this advantage, that he prosecuted his studies there with a definite aim and purpose, and with a determinate desire to master certain special branches of education required for the successful pursuit of his intended business.

Accordingly, we are not surprised to find that in the course of a few months he outstripped all his schoolfellows, and took the first place in the school. A curious record of his proficiency as a scholar is to be found in a work by Mr. David Loch, Inspector-General of Fisheries, published in 1779.* It was his duty to hold a court of the herring skippers of Dunbar, then the principal fishing-station on the east coast; and it appears that at one of his visits to the town he attended an examination of the burgh schools, and was so much pleased with the proficiency of the pupils that he makes special mention of it in his book.

After speaking of the teachers of Latin, English, and arithmetic, he goes on to say: "But Mr. Gibson, teacher of mathematics, afforded a more conspicuous proof of his abilities, by the precision and clearness of his manner in stating the questions which he put to the scholars; and their correct and spirited answers to his propositions, and their clear demonstrations of his problems, afforded the highest satisfaction to a numerous audience. And here I must notice in a particular manner the singular proficiency of a young man of the name of Rennie. He was intended for a millwright, and was breeding to that business under the famous Mr. Meikle, at Linton, East Lothian. He had not then attended Mr. Gibson for the mathematics much more than six months, but on his examination he discovered such amazing power of genius, that one would have imagined him a second Newton. No problem was too hard for him to demonstrate. With a clear head, a decent address, and a distinct delivery, he gave ready solutions to questions in natural and experimental philosophy, and also the reasons of the connection between causes and effects, the power of gravitation, &c., in so masterly and convincing a manner, that every person present admired such an uncommon stock of knowledge amassed at his time of life. If this young man is spared, and continues to prosecute his studies, he will do great honour to his country."

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* 'Essays on the Trade, Commerce, Manufactures, and Fisheries of Scotland.'

Rennie remained with Mr. Gibson for about two years. During that period he went as far in mathematics and natural philosophy as his teacher could carry him; after which he again proposed to return to Meikle's workshop. But about this time the mathematical master was promoted to a higher charge – the rectorship of the High School of Perth—and a question arose as to the appointment of his successor. The loss to the town was felt to be great, and Mr. Gibson was pressed by the magistrates to point out some person whom he thought suitable for the office. The only one he could think of was his favourite pupil; and though not quite seventeen years old, he strongly recommended John Rennie to accept the appointment.

The young man, however, already beginning to be conscious of his powers, had formed more extensive views of life, and could not entertain the idea of settling down as the "dominie" of a burgh school, respectable and responsible though that office might be. He accordingly declined the honour which the magistrates proposed to confer upon him, but agreed to take charge of the mathematical classes until Mr. Gibson's successor could be appointed. He continued to carry on the classes for about six weeks, and conducted them so satisfactorily that it was matter of much regret when he left the school and returned to his family at Phantassie for the purpose of prosecuting his intended profession.

CHAPTER II.

RENNIE'S MASTER—ANDREW MEIKLE.

ANDREW FLETCHER, of Saltoun, fled into Holland during the political troubles in the reign of Charles II., and during his residence there, he was particularly struck by the expert methods employed by the Dutch in winnowing corn and shealing barley. The chaff was then ordinarily separated from the corn by means of wind upon a knoll, or a draught of air blowing through the barn-door; and barley was shealed by pounding the grains with water in the hollow of a stone, until by that means the husks were rubbed off.

Fletcher saw that there was a great waste of labour and food in these processes—for oat- and barley-meal formed the principal food of Scotland—and during his residence abroad he determined to introduce the Dutch methods into his own country. Writing home to his brother, he desired him to send out to Holland one James Meikle, an ingenious country wright of Wester Keith,* for the purpose of learning the above arts and importing the requisite machinery into Scotland.

After a stay of about two months in that country, Meikle returned home, bringing with him a winnowing machine, commonly called a pair of fanners, and the iron-work requisite for a barley-mill. These were safely transported to Leith, and afterwards conveyed to Saltoun, where the barley-mill was erected and set to work; and for many years it was the only machine of the kind in the British dominions—so slow were people in those days to copy the improvements of their neighbours. "Saltoun barley" was the name by which dressed pot-barley then became known, and it continued to preserve the name long after barley-mills had come into general use.

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* It would seem that the ancestors of Meikle were held in esteem as ingenious workmen for generations; the Scots Parliament having, in 1686, passed a special Act for the encouragement of John Meikle, founder, who, it appears was the first person to introduce the art of iron-founding into Scotland.

James Meikle was equally successful in constructing his fanners for winnowing corn; but they had much superstitious prejudice to encounter,—the country people looking upon the grain cleaned by them with suspicion, as procured by "artificially-created wind." The clergy even argued that "winds were raised by God alone, and it was irreligious in man to attempt to raise wind for himself, and by efforts of his own;" and one clergyman even refused the holy communion to such of his parishioners as irreverently raised "Devil's wind." The readers of 'Old Mortality' will remember Mause Headrigg's indignation when it was proposed that her "son Cuddie should work in the barn wi' a new-fangled machine for dightin' the corn frae the chaff, thus impiously thwarting the will of Divine Providence by raising wind for your leddyship's ain particular use by human art, instead of soliciting it by prayer, or waiting patiently for whatever dispensation of wind Providence was pleased to send upon the shealing-hill." Scott, however, was obviously guilty of an anachronism in this passage, for the first pair of fanners was not set up at Saltoun until the year 1720—long after the period of Cuddie Headrigg's supposed trial—and it was not until seventeen years later that another winnowing-machine was set up in the neighbouring shire of Roxburgh, and employed as an ordinary agency in farming operations.

Andrew Meikle was the only surviving son of Fletcher's millwright, and like him was a clever mechanic. He had married and settled at Houston Mill, on James Rennie's Phantassie estate, where he combined the occupations of small farmer, miller, and millwright. He had himself fitted up the machinery of the mill, of which he was the tenant; and adjoining it was his millwright's shop, where he carried on his small business in connection with millwork—the demands of the district being as yet of an extremely limited character.

Houston Mill. [By E. M. Wimperis, after a Drawing by J. S. Smiles.]

But the march of agricultural improvement had by this time fairly begun in East Lothian.* The public spirit displayed by Fletcher of Saltoun was imitated by his neighbours. But probably the gentleman who gave the greatest impulse to agricultural progress in the county, which shortly after extended itself over Scotland, was Mr. Cockburn of Ormiston, to whom belongs the honour of adopting the system of long leases. He early became convinced that the surest way of stimulating the industry of the farmer was to give him a substantial interest in the improvement of the land which he farmed. One of his tenants having enclosed his fields with hedges and ditches at his own cost - the first farmer in Scotland who adopted the practice[*]—his landlord, to encourage his spirit of improvement, granted him a lease of his farm for nineteen years, renewable at the expiry of that term for a like period.

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* The Marquis of Tweeddale introduced the turnip into the county in 1740; the Earl of Haddington and Mr. Walker of Beanston, first adopted the system of fallowing land and *sowing broad clover* and rye-grass. Lord Elibank and Sir Hew Dalrymple divided between them the merit of inventing or introducing the practice of

The results were found so satisfactory, that Mr. Cockburn was induced to extend the practice, and before long it became generally adopted throughout the county. From that point agriculture advanced with extraordinary rapidity. The more thriving farmers sent their sons into England—a practice long since reversed—to learn the best methods of farming: they employed better implements and improved methods of culture; their landlords, further to encourage them, built more commodious steadings and farmhouses; and they were greatly helped in this course by the unusual facilities for obtaining credit which persons of standing and property possessed, on the general extension, from about the middle of last century, of what is called the Scotch system of banking.[†]

These measures soon put an entirely new face on the country. The distinction of "in-field" and "out-field" altogether ceased. Farms became completely enclosed, and sheep and black cattle were no longer allowed to roam

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under-draining; and Sir George Suttie first employed the Norfolk system of rotation of crops.

[*] Brown on 'Rural Affairs.'

[†] See Adam Smith's 'Wealth of Nations,' Book II., Chap. 2.

at large. Fields were thrown together, and small holdings consolidated into large ones. The moorland and the bog were reclaimed and converted into fruitful farms. A single instance, of some historical interest, may be given When the Royal army lay upon the field of Prestonpans in 1745, their front was "protected by a deep bog," across which Robert Anderson, a young gentleman of the county, who knew every foot of the ground, contrived to lead the Pretender's army by a path known only to himself. That bog, like so many others, has long since been reclaimed by drainage and cultivation, and now forms part of one of the most fertile farms in the Lothians.

Such was the improving state of affairs in East Lothian when Andrew Meikle began business at Houston Mill. His reputation as a mechanic and his skill in millwork were such, that he was usually employed in repairing and erecting mills in his own and the adjoining counties. Being an ingenious and thoughtful man, he eagerly turned his attention to the improvement of agricultural machinery, more especially of that connected with the thrashing, winnowing, dressing, and grinding of grain. Thus, as early as the year 1768, we find him taking out a patent - one of the very first taken out by any Scotch mechanic - for a new machine contrived by him for dressing and cleansing corn.* It was a combination of the riddle and fanners; and, though of no great novelty, it showed the direction in which his inventive faculties were at work.

Nothing caused so much loss and vexation to the farmer in former times as the operation of separating the corn from the straw. In some countries it was trodden out by cattle; hence the Biblical proverb, "Thou shalt not muzzle the ox that treadeth out the corn." Sledges or trail-carts were also used for the same purpose; but the most common instrument employed was the flail. By either of these methods, however, the process of thrashing was slowly performed, whilst a considerable portion of the grain was damaged or lost.

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* Patent No. 896. The name of Robert Mackell (employed with James Watt in the survey of the "ditch canal" through Perthshire—see Life of Smeaton) was associated with that of Meikle in this patent; Mackell probably finding the money, and Meikle the brains.

Many attempts had been made before Meikle's time to invent a machine which should satisfactorily perform this operation; but without effect. An East Lothian gentleman, named Michael Menzies, contrived one upon the principle of the flail, arranging a number of flails so as to be worked by a water-wheel; but they were soon broken to pieces by the force with which they fell. Another experiment was made in 1758 by a Stirlingshire farmer, named Leckie, who invented a machine on the principle of the horizontal flax-mill. It consisted of a vertical shaft, with four cross-arms fixed in a box, and when set in motion the arms beat off the grain from the straw when let down upon them by hand. Though this machine succeeded very well in thrashing oats, it cut off the heads of every other kind of corn submitted to its operation.

Similar attempts were made about the same time by farmers in the south, more especially by Mr. Ilderton at Alnwick, Mr. Smart at Wark, and Mr. Oxley at Flodden, about 1772–3. The machine employed by these gentlemen was composed of a large drum, about six feet in diameter, resembling a sugar hogshead, round which were placed a number of fluted rollers, which pressed inwards upon the drum by means of springs. The corn, in passing the cylinder and rollers, was no doubt rubbed out; but a large proportion of it being bruised and damaged by the operation, this plan too was eventually abandoned. Mr. Oxley is said to have afterwards tried the plan of stripping the corn from the straw by means of a scutcher; but the machine constructed with this object did not answer, and it was also laid aside.

Mr. Kinloch,* of Gilmerton in East Lothian, had however seen the last-mentioned machine at work, and he conceived the idea of improving it. He accordingly had a model made, in which he contrived that the drum, mounted with four pieces of fluted wood, should work upon springs, pressing with less force upon the corn in the process of rubbing it out. This model was shown to Meikle, with whom Mr. Kinloch had many conversations on the subject; and at the millwright's suggestion several improvements were made in it, one of which was the substitution of smooth feeding rollers for fluted ones. When the model had been completed, Mr. Kinloch sent it to Houston Mill to be tried by the power of Meikle's water-wheel. On being set to work, however, it was driven to pieces in a few minutes; and the same fate befell a larger machine after the same model, which Mr. Kinloch got made for one of his tenants a few years later.

The best result of Mr. Kinloch's experiments was, that they had the effect of directing the inventive mind of Andrew Meikle to the subject. After several years' thinking and planning, he constructed a thrashing-machine, about the year 1776. It consisted of a number of flails fixed in a strong beam moved by a crank, which beat out the corn on two platforms, one on each side of the beam. The performance of this machine, in the presence of some East Lothian farmers who went to see it at work, was on the whole satisfactory,† yet it did not come up to Meikle's expectations. On one of the gentlemen observing that the flails and platforms probably would not bear the force of the stroke, the inventor replied, that in case the machine did not answer, he intended to try a method of beating out the corn by means of fixed scutchers or beaters.*

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* Afterwards Sir Francis Kinloch.

† The following is a literal copy of the memorandum which was drawn up and signed on the occasion:—

"Know Mill, 14th Feb, 1778.—We whose names are subjoined, desired by Andrew Meikle to witness an experiment of his threshing machine, mett this day, and after one hour's performance of said machine, with the assistance of one man to feed in and carry of the straw, dight and measured up one boll, and two forpits barly being of mean qualitie. We are of opinion that a Man, in the ordinary way of threshing, could not thresh above five, or 6 firlots at most, in one day. The machine being simple, we suppose one horse may worke it without an aditional man. The saving most be considerable.

"(Signed)

John Dudgeon, Tenent in Tyningham,
Robert Dick, Tenent in Hedderwik,
George Rennie, Tenent in Fantase
William Wilson, Tenent in Pleastown,
William Craig, Tyningham."

Accordingly he proceeded to work out this idea in practice, and after a few years he succeeded in perfecting his invention on this principle, which was entirely new. These scutchers, shod with iron, were fixed upon a strong beam or cylinder, which revolved with great velocity, and in the process of so revolving, beat off the corn instead of rubbing it off by pressure, as had been attempted by former contrivers. By dint of study and perseverance he succeeded at length in perfecting his machine; to which he added solid fluted feeding rollers, and afterwards a machine for shaking the straw, fanners for winnowing the corn, and other improvements.

Meikle is said to have been superintending a mill job at Leith, at the time when he was engaged in working out this contrivance in his mind. He was accustomed to walk there and back within the same day while his job was in hand, or a distance of about forty miles. He studied the subject during his journey, and would occasionally stop while travelling to draw a rapid diagram upon the road with his walking-stick. It is related of him that on one occasion, whilst very much engrossed with the subject of his thrashing-mill, he had, absorbed by his calculations, wandered considerably from the right path. He stopped short suddenly, and hastily sketching his plan on the road, exclaimed, "I have got it! I have got it!" Archimedes himself, when he cried "Eureka," could not have been more delighted than our millwright was at the happy upshot of his deliberations.

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* A Reply to an Address to the Public, but more particularly to the Landed Interest of Great Britain and Ireland, on the subject of the Threshing Machine. By John Sheriff Edinburgh 1811.

The first machine erected on Meikle's new principle was put up in 1787 for Mr. Stein of Kilbeggie, in Clackmannanshire, who had great difficulty in procuring a sufficient number of barnsmen for thrashing straw to litter the large stock of cattle he had on hand; but the novelty

Andrew Meikle. [By T. D. Scott, after Ruddock.]

of the experiment, and the doubt entertained by Mr. Stein as to the efficacy of the proposed machine, induced him to require, as a condition, that if it did not answer the intended purpose, Meikle was not to receive any payment for it. The result, however, proved quite satisfactory, and the thrashing-machine at Kilbeggie, which was driven by water power, long continued in good working order. The next he erected was for Mr. George Rennie, at Phantassie, in the same year; and by this time he had so perfected his machine as to enable it to be driven by water, wind, or horses. That at Phantassie was worked by horse-power. In 1788 Meikle took out a patent for his invention, describing himself in the specification as "engineer and machinist."*

The thrashing-machine proved to be one of the greatest boons ever conferred upon the husbandman, and effected an immense saving of labour as well as of corn. By its means from seventy to eighty bushels of oats, and from thirty to fifty bushels of wheat, might be thrashed and cleaned in an hour; and it is calculated to have effected a saving, as compared with the flail, of one-hundredth part of the whole corn thrashed, or equal to a value of not less than two millions sterling in Great Britain alone In the course of twenty years from the date of the patent about three hundred and fifty thrashing-mills were erected in East Lothian alone, at an estimated outlay of nearly forty thousand pounds; and, shortly after, it became generally adopted in England, and indeed all over the civilised world.

We regret, however, to add, that Meikle did not reap those pecuniary advantages from his invention, which a less modest and more pushing man would have done. Pirates fell upon him on all sides and deprived him of the fruits of his ingenuity, and even denied him any originality whatever. When growing old and infirm, Sir John Sinclair bestirred himself to raise a subscription in his behalf; and a sum of 1500*l*. was collected, which was invested for his benefit. Mr. Dempster, M.P., wrote to Sir John, when on his charitable mission in 1809: "Should your tour in East Lothian procure a suitable reward to the inventor of the thrashing-machine, it will redound much to your and the country's honour; our heathen ancestors would have assigned a place in heaven to Meikle."*

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* Patent No 1645: "Machine for separating Corn from Straw."

Smeaton knew Meikle intimately, and frequently met him in consultation respecting the arrangements of the Dalry Mills, near Edinburgh, and other works; and he was accustomed to say of him, that if he had possessed but one-half the address of other people, he would have rivalled all his contemporaries, and stood forth as one of the first mechanical engineers in the kingdom.

Among the various improvements which this ingenious mechanic introduced in millwork, were those in the sails of windmills. Before his time, these machines were liable to serious accidents on the occurrence of a sudden gale, or a shift in the direction of the wind. By Meikle's contrivance, the machinery was so arranged that the whole sails might be taken in or let out in half a minute, according as the wind required, by a person merely pulling a rope within the mill. The machinery was at the same time kept in more uniform motion, and all danger from sudden squalls completely avoided.

His additions to the power of water-wheels were also important, and on one occasion proved effectual in carrying out an improvement of a remarkable character in the county of Perth. This was neither more nor less than washing away into the river Forth some two thousand acres of peat moss, and thus laying bare an equivalent surface of arable land, now amongst the most valuable in the Carse of Stirling.

The Kincardine Moss was situated between the rivers Teith and Forth. It was seven feet in depth, laid upon a bottom of rich clay. In 1766 Lord Kaimes, who entered into possession of the Blair Drummond estate, to which it belonged, determined, if possible, to improve the tract of land; and it occurred to him that the easiest plan would be to wash the moss entirely away. But how was this to be done? The river Teith, which was the only available stream at hand, was employed to drive a corn-mill. But Lord Kaimes saw that it would answer his intended purpose if he could get possession of it. He accordingly made an arrangement by which he became owner of the mill, which he pulled down, and then turned the mill-stream in upon the moss. Labourers were set to work to cut away the stuff, which was thrown into the current, and much of it thus washed away. But the process was slow, and the clearing of the land had not advanced very far by the year 1783, when Lord Kaimes's son, Mr. Home Drummond, entered into possession of the estate. A thousand acres still remained, which he determined to get rid of, if possible, in a more summary manner than his predecessor had done.

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* 'Memoirs of Sir John Sinclair,' vol. ii. p. 99.

Mr. Drummond consulted several engineers—amongst others Mr. Whitworth, a pupil of Brindley's—who recommended one plan; but George Meikle, a millwright at Alloa, the son of Andrew, proposed another, the invention of his father; and Mr. Whitworth, with much candour and liberality, at once acknowledged its superiority to his own, and urged Mr. Drummond to adopt it. The invention consisted of a newly-contrived wheel, 28 feet in diameter and 10 feet broad, for raising water in a simple, economical, and powerful manner, at the rate of from 40 to 60 hogsheads a minute; and it was necessary to raise it about 17 feet, in order to reach the higher parts of the land. The machinery, on being erected, was set to work, and with such good results, that in the course of a very few years, four miles of barren moss was completely washed away, and the district was shortly after covered with thriving farmsteads, as it remains to this day.

Meikle was a thorough mechanical inventor, and, wherever he could, he endeavoured to save labour by means of machinery. Stories are still told in the neighbourhood in which he lived, of the contrivances he adopted with this object in his own household, some of which were of an amusing character. One day a woman came to the mill to get some barley ground, and was desired to sit down in the cottage hard by, until it was ready. With the first sound of the mill-wheels the cradle and churn at her side began to rock and to churn, as if influenced by some supernatural agency. No one was in the house besides herself at the time, and she rushed from it, frightened almost out of her wits. Such incidents as these brought an ill name on Andrew, and the neighbours declared of him that he was "no canny."

He was often sent for to great distances, for the purpose of repairing pumps or setting mills to rights. On one occasion, when he undertook to supply a gentleman's house with water, so many country mechanics had tried it before and failed, that the butler would not believe Meikle when he told him he would send in the water next day. Meikle, however, told him to get everything ready. "It will be time enough to get ready," said the incredulous butler, "when we see the water." Meikle pocketed the affront, but set his machinery to work early next morning; and when the butler got out of bed he found himself up to his knees in water, so successfully had the engineer performed his promise.

Meikle lived to an extreme old age, and was cheerful to the last. He was a capital player on the Northumbrian bagpipes. The instrument he played on was made by himself, the chanter being formed out of a deer's shank-bone. When ninety years old, at the family gatherings on "Auld Hansel Monday," his six sons and their numerous families danced about him to his music. He died in 1811, in his ninety-second year, and was buried in Prestonkirk churchyard, close by Houston Mill, where a simple monument is erected to his memory, bearing the following inscription:—

> "Beneath this Stone are deposited the remains of the late Andrew Meikle, civil engineer at Houston Mill, who died in the year 1811, aged 92 years. Descended from a race of ingenious mechanics, to whom the country for ages had been greatly indebted, he steadily followed the example of his ancestors, and, by inventing and bringing to perfection a machine for separating corn from the straw (constructed upon the principles of velocity, and furnished with fixed beaters or skutchers), rendered to the agriculturists of Britain and of other nations, a more beneficial service than any hitherto recorded in the annals of ancient or modern science." *

Such was the master who first trained and disciplined the skill of John Rennie, and implanted in his mind an enthusiasm for mechanical excellence. Another of his apprentices was a man who exercised almost as great an influence on the progress of mechanics, through the number of first-rate workmen whom he trained, as Rennie himself did in the art of engineering. We allude to Peter Nicholson, an admirable mechanic and architect, author of numerous works on carpentry and architecture, which to this day are amongst the best of their kind. We now pursue the career of Andrew Meikle's most distinguished pupil.

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* It is remarkable that Scotch biography should be altogether silent respecting this ingenious and useful workman. In the most elaborate of the Scotch biographical collections — that of Robert Chambers, in four large volumes — not a word occurs relating to Meikle. An article is devoted to Mickle, the translator of another man's invention in the shape of a poem, the 'Lusiad;' but the name of the inventor of the thrashing-machine is not even mentioned; affording a singular illustration of the neglect which this department of biography has heretofore experienced, though it has been by men such as Meikle, and not by poets, that this country has in a great measure been made what it is.

CHAPTER III.

RENNIE BEGINS BUSINESS AS MILLWRIGHT AND ENGINEER.

WE have now seen how Rennie was educated—at school and workshop—and how the ingenious Andrew Meikle was not the least useful of his schoolmasters.

On Rennie's return to Phantassie, after conducting for a time the burgh school at Dunbar, he continued to pursue his studies, especially in mathematics, mechanics, and natural philosophy. He also frequented the workshop of his friend Meikle, assisting him with his plans, and taking an especial interest in the invention of the thrashing-machine, which Meikle was at that time engaged in bringing to completion. He was also entrusted to superintend the repairs of corn-mills in cases where Meikle could not attend to them himself; and he was sent, on several occasions, to erect machinery at a considerable distance from Prestonkirk. Rennie thus gained much valuable experience, and acquired some confidence in his own powers.

He next began to undertake millwork on his own account. His brother George was already well known as a clever farmer, and the connection helped him to considerable employment. Meikle was also ready to recommend him in cases where he could not accept the work offered him in distant counties; and hence, as early as 1780, when Rennie was only nineteen years of age, we find him employed in fitting up the new mills at Invergowrie, near Dundee. He designed the machinery as well as the buildings for its reception, and superintended them to their completion.

His next work was to prepare an estimate and design for the repairs of Mr. Aitcheson's flour-mills at Bonnington, near Edinburgh. Here he employed cast-iron pinions, instead of the wooden trundles formerly used—one of the first attempts made to introduce iron into this portion of the machinery of mills.

These, his first essays in design, were considered very successful, and they brought him both money and fame. Business flowed in upon him, and before the end of his nineteenth year he had abundant employment. But he had no intention of confining himself to the business of a country millwright; for he aimed at a higher professional position, and a still wider field of work. Desirous, therefore, of advancing himself in scientific culture, and prosecuting those studies in mechanical philosophy which he had begun at Phantassie and pursued at Dunbar, he determined to enter himself a student at the University of Edinburgh. In taking this step he formed the resolution —by no means unusual amongst young men of even a humbler class—of supporting himself at college entirely by his own labour. He was persuaded that by diligence and assiduity he would be enabled to earn enough during the summer months to pay for his winter's instruction and maintenance; and his habits being frugal and his style of living very plain, he was enabled to prosecute his design without difficulty.

He accordingly matriculated at Edinburgh in November, 1780, and entered the classes of Dr. Robison, Professor of Natural Philosophy, and of Dr. Black, Professor of Chemistry— both men of the highest distinction in their respective walks. Robison was an eminently prepossessing person, frank and lively in manner, full of fancy and humour, and, though versatile in talent, a profound and vigorous thinker. His varied experience of life, and the thorough knowledge which he had acquired of the principles as well as the practice of the mechanical arts, proved of great use to him as an instructor of youth. The state of physical science was then at a very low ebb in this country, and the labours of Continental philosophers were but little known even to those who occupied the chairs in our Universities; the results of their elaborate researches concealed in foreign languages, or being known, at most, to a few inquirers more active and ardent than their fellows; while the general student, mechanic, and artisan, were left to draw their principal information from daily observation and experience.

Under Dr. Robison the study of natural philosophy became invested with unusual significance and importance. The range of his knowledge was most extensive: he was familiar with the whole circle of the accurate sciences, and in imparting information, his understanding seemed to work with extraordinary energy and rapidity. The labours of others rose in value under his hands, and new views and ingenious suggestions never failed to enliven his prelections on mechanics, hydrodynamics, astronomy, optics, electricity, and magnetism, the principles of which he unfolded to his pupils in language at once fluent, elegant, and precise. Lord Cockburn, in his 'Memorials,' remembers him as somewhat remarkable for the humour in which he indulged in the article of dress. "A pigtail so long and thin that it curled far down his back, and a pair of huge blue worsted hose, without soles, and covering the limbs from the heel to the top of the thigh, in which he both walked and lectured, seemed rather to improve his wise elephantine head and majestic person." He delighted in holding familiar intercourse with his pupils, whom he charmed and elevated by his brilliant conversation and his large and lofty views of life and philosophy. Rennie was admitted to his delightful society, and to the close of his career he was accustomed to look back upon the period which he spent at Edinburgh as amongst the most profitable and instructive in his life.

During his college career, Rennie carefully read the works of Emerson, Switzer, Maclaurin, Belidor, and Gravesande, allowing neither pleasure nor society to divert him from his studies. As a relief from graver topics, he set himself to learn the French and German languages, and was shortly enabled to read both with ease. His recreation was mostly of a solitary kind, and, having a little taste for music, he employed some of his leisure time in learning to play upon various instruments. He acquired considerable proficiency on the flute and the violin, and he even went so far as to buy a pair of bagpipes and learn to play upon them,—though the selection of such an instrument probably does not say much for his musical taste. When he left Edinburgh and entered seriously upon the business of life, the extensive nature of his engagements so completely occupied his time, that in a few years flute, fiddle, and bagpipes, were laid aside altogether.

During the three years that he attended college our student was busily occupied in the summer vacation—extending from the beginning of May to the end of October in each year—in executing millwork in various parts of the country. Amongst the undertakings on which he was thus employed, may be mentioned the repair or construction of the Kirkaldy and Bonnington Flour Mills, Proctor's Mill at Glammis, and the Carron Foundry Mills. When not engaged on distant works, his brother George's house at Phantassie was his headquarters, where he prepared his designs and specifications. He had the use of the workshop at Houston Mill for making such machinery as was intended for erection in the neighbourhood; but when he was employed at some distant point, the work was executed in the most convenient places he could find for the purpose. There were as yet no large manufactories in Scotland where machinery of an important character could be turned out as a whole; the millwright being under the necessity of sending one portion to the blacksmith, another to the founder, another to the brass-smith, and another to the carpenter—a state of things involving a great deal of trouble, and risk of failure,—but which was eminently calculated to familiarize our young engineer with the details of every description of work required in the practice of his profession.

His college training having ended in 1783, and being desirous of acquiring some knowledge of English engineering practice, Rennie set out on a tour through the manufacturing districts. Brindley's reputation attracted him first towards Lancashire, for the purpose of inspecting the works of the Bridgewater Canal. There being no stage coaches convenient for his purpose, he travelled on horseback, and in this way he was enabled readily to diverge from his route for the purpose of visiting any structure more interesting than ordinary. At Lancaster he inspected the handsome bridge across the Lune, then in course of construction by Mr. Harrison, afterwards more celebrated for his fine work of Chester Gaol. At Manchester he examined the works of the Bridgewater Canal; and at Liverpool he visited the docks then in progress.

Proceeding by easy stages to Birmingham, then the centre of the mechanical industry of England, and distinguished for the ingenuity of its workmen and the importance of its manufactures in metal, he took the opportunity of visiting the illustrious Boulton and Watt at Soho. His friend, Dr. Robison, had furnished him with a letter of introduction to James Watt, who received the young engineer kindly and showed him every attention; and a friendship then began which lasted until the close of Watt's life.

The condensing-engine had by this time been brought into an efficient working state, and was found capable not only of pumping water—almost the only purpose for which it had originally been intended—but of driving machinery, though whether with advantageous results was still a matter of doubt. Thus, in November, 1782, Watt wrote to his partner Boulton, "There is now no doubt but that fire-engines will drive mills, but I entertain some doubts whether anything is to be got by them." About the beginning of March, 1783, however, a company was formed in London for the purpose of erecting a large corn-mill, to be driven by one of Boulton and Watt's steam-engines, and the work was in progress at the time that Rennie visited Soho. Watt had much conversation with his visitor on the subject of corn-mill machinery, and was gratified to learn the extent and accuracy of his information. He seems to have been provoked beyond measure by the incompetency of his own workmen. "Our millwrights," he wrote to his partner, "have kept working, working, at the corn-mill ever since you went away, and it is not yet finished; but my patience being exhausted, I have told them that it must be at an end to-morrow, done or undone. There is no end of millwrights once you give them leave to set about what they call machinery; here they have multiplied wheels upon wheels until it has now almost as many as an orrery."

Watt himself had but little knowledge of millwork, and stood greatly in need of some intelligent millwright to take charge of the fitting up of the Albion Mills. Young Rennie seemed to him to be a very likely person; but, with characteristic caution, he said nothing to him of his intentions, but determined to write privately to his friend Robison upon the subject, requesting particularly to know his opinion as to the young man's qualifications for taking the superintendence of such important works. Dr. Robison's answer was decided; his opinion of Rennie's character and ability was so favourable, and expressed in so confident a tone, that Watt no longer hesitated; and he wrote to the young engineer, after he had returned home, inviting him to undertake the supervision of the proposed Albion Mills, so far as concerned the planning and erection of the requisite machinery.

Watt's invitation found Rennie again in full employment. He was engaged in designing and erecting mills and machinery of different kinds. Among his earlier works, we also find him, in 1784, when only in his twenty-third year, occupied in superintending the building of his first bridge--the forerunner of a series of structures which have not been surpassed in any age or country. His earliest bridge was erected for the trustees of the county of Mid-Lothian, across the Water of Leith, near Steven-[illegible] Mill, about two miles west of Edinburgh. It is [illegible] bridge on the Edinburgh and Glasgow turnpike-road.

Rennie's first Bridge.

Notwithstanding the extent of his engagements, and his prospects of remunerative employment, Rennie looked upon the invitation of Watt as a favourable opportunity for enlarging his experience, and, after due deliberation, he replied accepting the appointment. He proceeded, however, to finish the works he had in hand, after which, taking leave of his friends at Phantassie, he set out for Birmingham on the 19th of September, 1784. He remained there for two months, during which he enjoyed the closest personal intercourse with Watt and Boulton, and was freely admitted to their works at Soho, which had already become the most important of their kind in the kingdom.

Birmingham was then the centre of the mechanical industry of England. For many centuries, working in metals had been the staple trade of the place. Swords were made there in the time of the ancient Britons. In the reign of Henry VIII., Leland found "many smythes in the town that use to make knives and all manner of cutting tools, and many loriners that make bittes, and a great many nailers; so that a great part of the town is maintained by smythes who have their iron and sea-coal out of Staffordshire."

The artisans of the place thus had the advantage of the training of many generations; aptitude for handicraft, like every other characteristic of a people, descending from father to son like an inheritance. There was then no town in England where mechanics were to be found so capable of satisfactorily executing original and unaccustomed work, nor has the skill yet departed from them. Though there are now many districts in which far more machinery is manufactured than in Birmingham, the workmen of that place are still superior to most others in executing machinery requiring manipulative skill and dexterity out of the common track, and especially in carrying out new designs. The occupation of the people gave them an air of quickness and intelligence which was quite new to strangers accustomed to the quieter aspects of rural life. When Hutton entered Birmingham, he was especially struck by the vivacity of the persons he met in the streets. "I had," he says, "been among dreamers, but now I was among men awake. Their very step showed alacrity. Every man seemed to know and prosecute his own affairs." He also adds, that men whose former disposition was idleness no sooner breathed the air of Birmingham than diligence became their characteristic.

Rennie did not stand in need of this infection being communicated to him, yet he was all the better for his contact with the population of the town. He made himself familiar with their processes of handicraft, and, being able to work at the anvil himself, he could fully appreciate the skill of the Birmingham artisans. The manufacture of steam-engines at Soho chiefly attracted his notice and his study. He had already made himself acquainted with the principles as well as the mechanical details of the steam-engine, and was ready to suggest improvements, in a very modest way, even to Watt himself, who was still engaged in perfecting his wonderful invention.

The partners thought that they saw in him a possible future competitor in their trade: and in the agreement which they entered into with him as to the erection of the Albion Mills, they sought to bind him, in express terms, not only to abstain from interfering in any way with the construction and working of the steam-engines required for the mills, but to prohibit him from executing such work upon his own account at any future period. Though ready to give his word of honour that he would not in any way interfere with Watt's patents, he firmly refused to bind himself to such conditions; being resolved in his own mind not to be debarred from making such improvements in the steam-engine as experience might prove to be desirable. And on this honourable understanding the agreement was concluded; nor did Rennie ever in any way violate it, but retained to the last the friendship and esteem of both Boulton and Watt.

On the 24th of November following, after making himself fully acquainted with the arrangements of the engines by means of which his machinery was to be driven, our engineer set out for London to proceed with the designing of the millwork. It was also necessary that the plans of the building - which had been prepared by Mr. Samuel Wyatt, an architect of reputation in his day should undergo revision; and, after careful consideration, Rennie made an elaborate report on the subject, recommending various alterations, which were approved by Boulton and Watt, and forthwith ordered to be carried into effect.

CHAPTER IV.

The Albion Mills—Mr. Rennie as Engineer.

When Rennie arrived in London in 1785, the country was in a state of serious depression in consequence of the unsuccessful termination of the American War. Parliament was engaged in defraying the heavy cost of the recent struggle with the revolted colonies. The people were ill at ease, and grumbled at the increase of the debt and taxes. The unruly population of the capital could with difficulty be kept in order. The police and local government were most inefficient. Only a few years before, London had, during the Gordon riots, been for several days in the hands of the mob, and blackened ruins in different parts of the city still marked the track of the rioters.

Though the largest city in Europe, the population of London was scarcely more than a third of what it is now; yet it was thought that it had become so vast as to be unmanageable. Its northern threshold was at Hicks's Hall, in Clerkenwell. Somers Town, Camden Town, and Tyburnia were as yet green fields, and Kensington, Chelsea, Marylebone, and Bermondsey were outlying villages. Fields and hedgerows led to the hills of Highgate and Hampstead. The West End of London was a thinly-inhabited suburb. A wide tract of marshy ground extended opposite Lambeth. The westernmost building in Westminster was Millbank. Executions were conducted in Tyburn fields, now known as Tyburnia, down to 1783. Oxford Street, from Princes Street eastward as far as High Street, St. Giles's, had only a few houses on the north side. "I remember it," says Pennant, "a deep hollow road and full of sloughs, with here and there a ragged house, the lurking-place of cut-throats; insomuch that I was never taken that way by night, in my hackney-coach, to a worthy uncle's who gave me lodgings at his house in George Street, but I went in dread the whole way."

Paddington was "in the country," and the communication with it was kept up by means of a daily stage - a lumbering vehicle, driven by its proprietor -- which was heavily dragged into the city in the morning, down Gray's Inn Lane, with a rest at the Blue Posts, Holborn Bars, to give passengers an opportunity of doing their shopping. The morning journey was performed in two hours and a half, "quick time," and the return journey in the evening in about three hours.

Heavy coaches still lumbered along the country roads at little more than four miles an hour. A new state of things had, however, been recently inaugurated by the starting of the first mail-coach on Palmer's plan, which began running between London and Bristol on the 24th of August, 1784, and the system was shortly extended to other places. Numerous Acts were passed by Parliament authorising the formation of turnpike-roads and the erection of bridges.* The general commerce of the country was also making progress. The application of recent inventions in manufacturing industry gave a stimulus to the general improvement, and this was further helped by a succession of favourable harvests. The India Bill had just been renewed by Pitt, and trade with India was brisk. A commercial treaty with France was on foot, from which great things were expected, but the outbreak of the Revolution, which shortly after took place, put an end for a time to those hopes of fraternity and peaceful trade in which it had originated. The Government boldly interposed to check smuggling, and Pitt sent a regiment of soldiers to burn the smugglers' boats laid up on Deal beach by the severity of the winter, so that the honest traders might have the full benefit of the treaty with France which Pitt had secured. Increased trade flowed into the Thames, and ministers and monarch indulged in drawing glowing pictures of prosperity.

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* In the interval between 1784 and 1792, not fewer than 302 Acts were passed authorising the construction of new roads and bridges, 64 authorising the formation of canals and harbours, and still more numerous Acts for carrying out measures of drainage, enclosure, paving, and other local improvements—a sufficient indication of the industrial activity of the nation at that time.

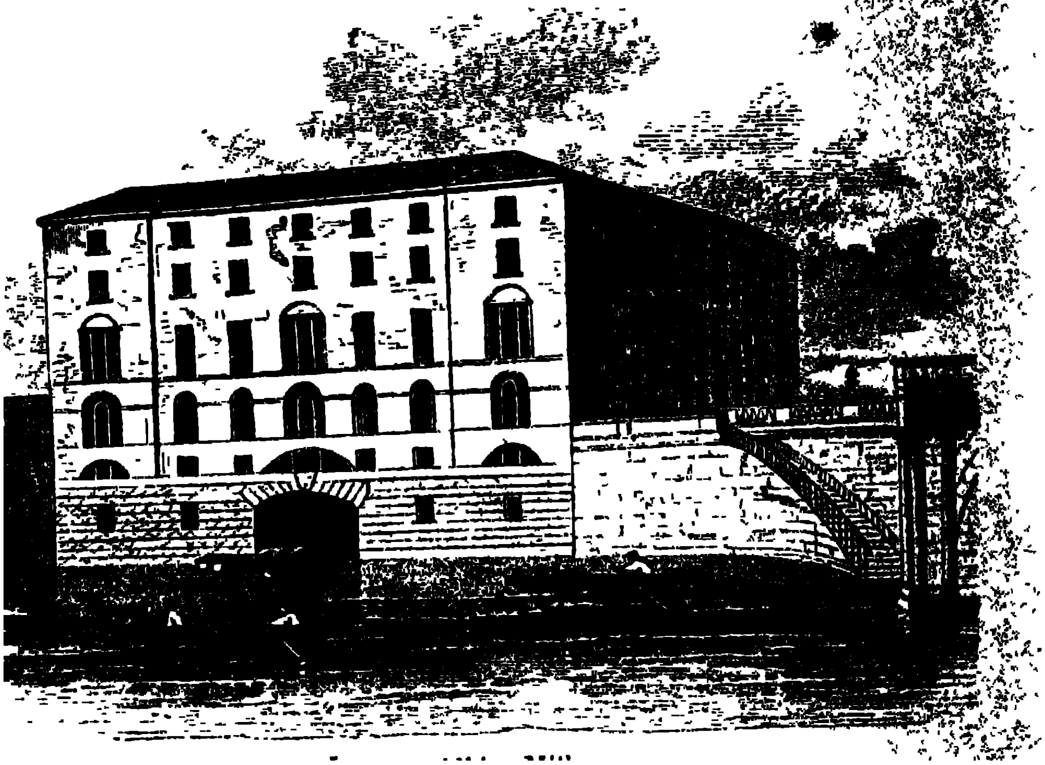
When Pennant visited London in 1790, he found the river covered with shipping, presenting a double forest of masts, with a narrow avenue in mid-channel. The smaller vessels discharged directly into the warehouses along the banks of the river, whilst the India ships of large burden mostly lay down the river as far as Blackwall, and discharged into lighters, which floated up their cargoes to the city wharves. London as yet possessed no public docks—only a few private ones, open to the river, of very limited extent,—although Pennant speaks of Mr. Perry's dock and ship-yard at Blackwall, on the eastern side of the Isle of Dogs, as "the greatest private dock in all Europe!" Another was St. Saviour's, denominated by Pennant "the port of Southwark," though it was only thirty feet wide, and used for discharging barges of coal, corn, and other commodities. There was also the Execution Dock at Wapping, which witnessed the occasional despatch of seagoing criminals, who were hanged on a gallows at low-water mark, and left there until the tide flowed over their dead bodies.

Among the commercial enterprises to which the increasing speculation of the times gave birth, was the erection of the Albion Mills. For the more convenient transit of corn and flour, as well as to secure a plentiful supply of water for engine purposes, it was determined to erect the new mills on the banks of the Thames, near the south-east end of Blackfriars Bridge. Hand-mills, which had in the first place been used for pounding wheat into flour, had long since been displaced by water-mills and windmills; and now a new agency was about to be employed, of greater power than either—the agency of steam.

Fire-engines, or steam-engines, had heretofore been employed almost exclusively to pump water out of mines; but the possibility of adapting them to the driving of machinery having been suggested to the inventive mind of James Watt, he set himself at once to the solution of the problem, and the result was the engines for the Albion Mills—the most complete and powerful which had been produced by the Soho manufactory. They consisted of two double-acting engines, of the power of 50 horses each, with a pressure of steam of five pounds to the superficial inch—the two engines, when acting together, working with the power of 150 horses. They drove twenty pairs of millstones, each four feet six inches in diameter, twelve of which were usually worked together, each pair grinding ten bushels of wheat per hour, by day and night if necessary. The two engines working together were capable of grinding, dressing, &c., complete, 150 bushels an hour—by far the greatest performance achieved by any mill at that time, and probably not since surpassed.

But the engine power was also applied to a diversity of other purposes, then altogether novel—such as hoisting and lowering the corn and flour, loading and unloading the barges, and in the processes of fanning, sifting, and dressing—so that the Albion Mills came to be regarded as among the greatest mechanical wonders of the day. The details of these various ingenious arrangements were entirely worked out by Mr. Rennie himself, and they occupied him nearly four years in all, having been commenced in 1784, and finished in 1788. Mr. Watt was so much satisfied with the result of his employment of Rennie, that he wrote to Dr. Robison, thanking him for his recommendation of his young friend, and speaking in

he highest terms of the ability with which he had de-
igned and executed the millwork and set the whole in
peration.



The Albion Mills.

Amongst those who visited the new mills and carefully inspected them was Mr. Smeaton, the engineer, who pronounced them to be the most complete, in their arrangement and execution, which had yet been erected in any country; and though naturally an undemonstrative person, he cordially congratulated Mr. Rennie on his success.

The completion of the Albion Mills, indeed, marked an important stage in the history of mechanical improvements; and they may be said to have effected an entire revolution in millwork generally. Until then, machinery had been constructed almost entirely of wood; it was clumsy, and involved great friction and waste of power. Smeaton had introduced an iron wheel at Carron in 1754, and afterwards in a mill at Belper, in Derbyshire—mere rough castings, imperfectly executed, and neither chipped not tied to any particular form; and Murdock (James Watt's ingenious assistant) had also employed cast-iron work to a limited extent in a mill erected by him in Ayrshire; but these were very inferior specimens of iron work, and exercised no general influence on mechanical improvement.

Mr. Rennie's adoption of wrought- and cast-iron wheels was of much greater importance, and was soon adopted in all large machinery. The whole of the wheels and shafts of the Albion Mills were of iron, with the exception occasionally of the cogs, which were of hard wood, working into other cogs of cast iron; but where the pinions were very small, they were made of wrought iron. The teeth, both wooden and iron, were accurately formed by chipping and filing to the form of epicycloids. The shafts and axles were of iron and the bearings of brass, all accurately fitted and adjusted, so that the power employed worked to the greatest advantage and at the least possible loss by friction. The machinery of the Albion Mills, as a whole, was regarded as the finest that had been executed up to that date, and formed the model for future engineers to work by. Although Mr. Rennie executed many splendid specimens of machinery in his after career,* he himself was accustomed to say that the Albion Mill machinery was the father of them all.

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* Shortly after the completion of these mills, Mr. Rennie was largely consulted on the subject of machinery of all kinds. The Corporations of London, Edinburgh, Glasgow, Perth and other places, took his advice as to flour-mills. Agriculturists consulted him about thrashing-mills, millers about grinding-mills, and manufacturers and distillers respecting the better arrangement of their works. In July, 1798, he was called upon to examine the machinery and arrangements at the Royal Mint on Tower Hill. The result was, the construction of an entire new mint worked by steam-power, with improved rolling, cutting-out and stamping machinery, after Mr. Rennie's designs. The new machinery was introduced between the years 1806 and 1810. The cutting-out and stamping machines were the invention of the late Matthew Boulton of Soho; but the machinery was by Rennie. On one occasion, in 1819, a million of sovereigns was turned out in eight days! During the great silver coinage in 1826 the eight presses turned out for nine months not less than 247,696 pieces per day, the rolling going

As a commercial enterprise, the mills promised to be successful: they were kept constantly employed, and were likely to realise a handsome profit to their proprietors, when unhappily they were destroyed by fire on the 3rd of March, 1791, only three years after their completion. Their erection had been viewed with great hostility by "the trade," and the projectors were grossly calumniated on the ground that they were establishing a monopoly injurious to the public; which was sufficiently disproved by the fact that the mills were the means of considerably reducing the price of flour while they continued in operation. The circumstances connected with the origin of the fire were never cleared up, and it was generally believed at the time that it was the work of an incendiary.

During the night when the buildings were destroyed, Mr. Rennie, who lived near at hand, felt unaccountably anxious. A presentiment as of some great calamity hung over him, which he could not explain to himself or to others. He went to bed at an early hour, but could not sleep. Several times he went off in a doze, and suddenly woke up, having dreamt that the mills were on fire! He rose, looked out, and all was quiet. He went to bed again, and at last fell into a profound sleep, from which he was roused by the cry of "Fire!" under his windows, and the rumble of the fire-engines on their way to the mills! He dressed hastily, rushed out, and to his dismay found his chef-d'œuvre wrapt in flames which brightened the midnight sky. The engineer was amongst the foremost in his efforts to extinguish the conflagration; but in vain. The fire had made too great progress, and the Albion Mills,

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on day and night, and the stamping for fifteen hours out of every twenty-four. Mr. Rennie also supplied the machinery for the mints at Calcutta and Bombay; that erected at the former place being capable of turning out 200,000 pieces of silver in every eight hours.

Rennie's pride, were burnt completely to the ground, and were never rebuilt.

The Albion Mills, however, established Mr. Rennie's reputation as a mechanical engineer, and introduced him to extensive employment. His practical knowledge of masonry and carpentry also served to point him out as a capable man in works of civil engineering, which were in those days usually entrusted to men bred to practical mechanics.

There was not as yet any special class trained to the profession of engineering, and the number of persons who followed it was very small. Engineers were the product of circumstances, and of their instinct for construction; and this was often the instinct of genius. Hence they were mainly self-educated: Smeaton and Watt being mathematical instrument makers, Telford a stonemason, and Brindley and Rennie millwrights; force of character and bent of genius enabling each to carve out his career in his own way.

There was very little previous practice to serve for their guide. When they were called upon to undertake works of an entirely original character, and could not find an old road, they had to make a new one. This threw them upon their resources, and compelled them to be inventive: it practised their powers and disciplined their skill, and in course of time the habitual encounter with difficulties brought fully out their character as men, as well as their genius as engineers.

When the ruins of the Albion Mills had been cleared away, Mr. Rennie obtained leave from the owners to erect a workshop on a landing-wharf in Holland Street, a little below the site of the mills, where he afterwards carried on the business of a mechanical engineer.* But from an early period the civil branch of the profession occupied a considerable share of his attention, and eventually it became his principal pursuit; though down to the year 1788 he was chiefly occupied in designing and constructing machinery for dye-works, water-works (at London Bridge, amongst others), flour-mills, and rolling-mills, in all of which Boulton and Watt's engine was the motive power employed.

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* His first place of business was at Old Jamaica Wharf, Upper Ground Street, Lambeth.

Among the friends whom Mr. Rennie's practical abilities attracted about this time, was the eccentric but ingenious Earl Stanhope, who frequently visited his works, to see what was going on in the mechanical line. His Lordship was himself one of the busiest mechanical projectors of his day, and England owes him a debt of gratitude for his valuable inventions, one of the most useful of which was the printing press which bears his name. He also made important improvements in the process of stereotype printing; in the construction of locks and canals; and among his lighter efforts may be mentioned the contrivance of an ingenious machine for performing arithmetical operations.

Lord Stanhope especially delighted in the society of clever mechanics, in whose art he took great pleasure; because he could thoroughly understand it. He was, indeed, a first-rate workman himself. His father-in-law, the Earl of Chatham, said of him, that "Charles Stanhope, as a carpenter, a blacksmith, or millwright, could in any country or in any times preserve his independence and bring up his family in honest and industrious courses, without soliciting the bounty of friends or the charity of strangers." Lord Stanhope even insisted that his children should devote themselves to acquire an industrious calling, as he himself had done,—believing that a time of public calamity was approaching (arising from the extension of French revolutionary principles), which would render it necessary for every person to depend for their livelihood upon their own personal labour and skill. Indeed a serious difficulty occurred between him and his wife on this very point, which ended in a separation; and the story went abroad that the Earl was crazed.

The application of the power of the steam-engine to the purposes of navigation was one of the subjects in which Lord Stanhope took a more than ordinary interest. As early as the year 1790—before Fulton had applied his mind to the subject—he was in communication with Mr. Rennie as to the best mode of applying this novel power, and in that year he took out his patent for the propulsion of ships by steam; but his plan, though ingenious, was never carried into practical effect.* On the 26th of April, 1790, we find Mr. Rennie, in a letter to the Earl, communicating the information which he had required as to the cost of applying Boulton and Watt's improved steam-engine to his newly-invented method of propelling ships without sails.

Lord Stanhope had also, it appeared, taken objection to the space occupied by the condensing apparatus, and wished to know whether it could not be dispensed with, so that room might be economized. To this Mr. Rennie replied that it could, and that high-pressure steam might be employed if necessary; also that the cylinders might be used inclined or vertically, as best suited the space available for their accommodation. His Lordship proceeded to perfect his invention, and made a trial of its powers in Greenland Dock with a flat-bottomed boat constructed for the purpose; but the vessel not moving with a velocity greater than three miles an hour, the plan was eventually abandoned.

Shortly after the retirement of Mr. Smeaton from the profession, about the end of the year 1791, Mr. Rennie was consulted respecting numerous important canal undertakings projected in different parts of the country. Amongst them were a proposed navigation to connect Cambridge with Bury St. Edmunds—another between Andover and Salisbury—and a third between Reading and

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* He adopted paddles, placed under the quarters of the vessel, which were made to open and shut like the feet of a duck.

Bath, which was afterwards carried out by him as the Kennet and Avon Canal. On this, his first work of civil engineering in England, he bestowed great pains,—on the survey, the designs for the viaducts and bridges, as well as on the execution of the works themselves.

The Kennet and Avon Canal commences at Newbury, at the head of the River Kennet Navigation, passes up the vale of the Kennet for 16½ miles by Hungerford to Crofton, where the summit level begins, which is reached by 31 locks, rising in all 210 feet. It then proceeds by Burnslade, Wootton Rivers, and the valley of the Pewsey, to Devizes; and from Devizes by Foxhanger, Semington, Bradford, and the vale of the Avon to Bath, joining that river just above the Old Bath Bridge, where the Bristol navigation terminates. The total length of the canal is 57 miles, the total descent on the west side of the summit being 404 feet 6 inches, divided into 48 locks. The Kennet is crossed several times,—at Hungerford by a brick aqueduct of three arches. At the summit a tunnel 500 yards in extent was necessary, approached by deep cuttings.

The strata between Wootton Rivers and Devizes being mostly open chalk and sand, great difficulty was experienced in forming a water-tight bed for the canal, as well as in preventing slips of the adjacent ground. At that part of the line which lies between the river Biss and Trowbridge, the works were carried along the face of a steep slippery hill. Then near Bradford the cutting is mostly through open rock, and beyond that through beds of tough clay interspersed with strata of fuller's earth. The water at these points worked serious mischief, for after a heavy fall of rain it would filter through the earth, and the weight of the mass pressing down from above, tended to force out the soft clay, causing extensive slips. On one occasion not less than seven acres of land slid into the canal, forcing the whole down into the river in the valley below. To remedy this source of mischief, soughs or small tunnels were carried into the hillside for a considerable distance, at a level much below that of the canal. These again were crossed by other intercepting drains, so that numerous distinct outlets were provided for the water to prevent its reaching the canal works,—which were thus made to stand firm, after great difficulties had been overcome, and much expense incurred.

Besides these works there were the usual bridges, aqueducts, culverts, &c., all of which were executed in a substantial manner. Among the finest architectural structures forming part of the canal, is the aqueduct over the river Avon, about a mile from Limpley Stoke and six miles from Bath, which is greatly admired for the beauty of its elevation; and indeed, wherever there is an aqueduct or a bridge upon the line of this canal, it will be found excellent in workmanship and tasteful in design. As a whole, the navigation was pronounced to be one of the best executed in the kingdom; and the works have stood admirably down to the present time. In a commercial and national point of view the undertaking was of considerable importance, connecting as it did the navigation of the metropolis with that of Bristol and St. George's Channel, as well as opening up an extensive intermediate district; although it did not prove very remunerative to its proprietors.

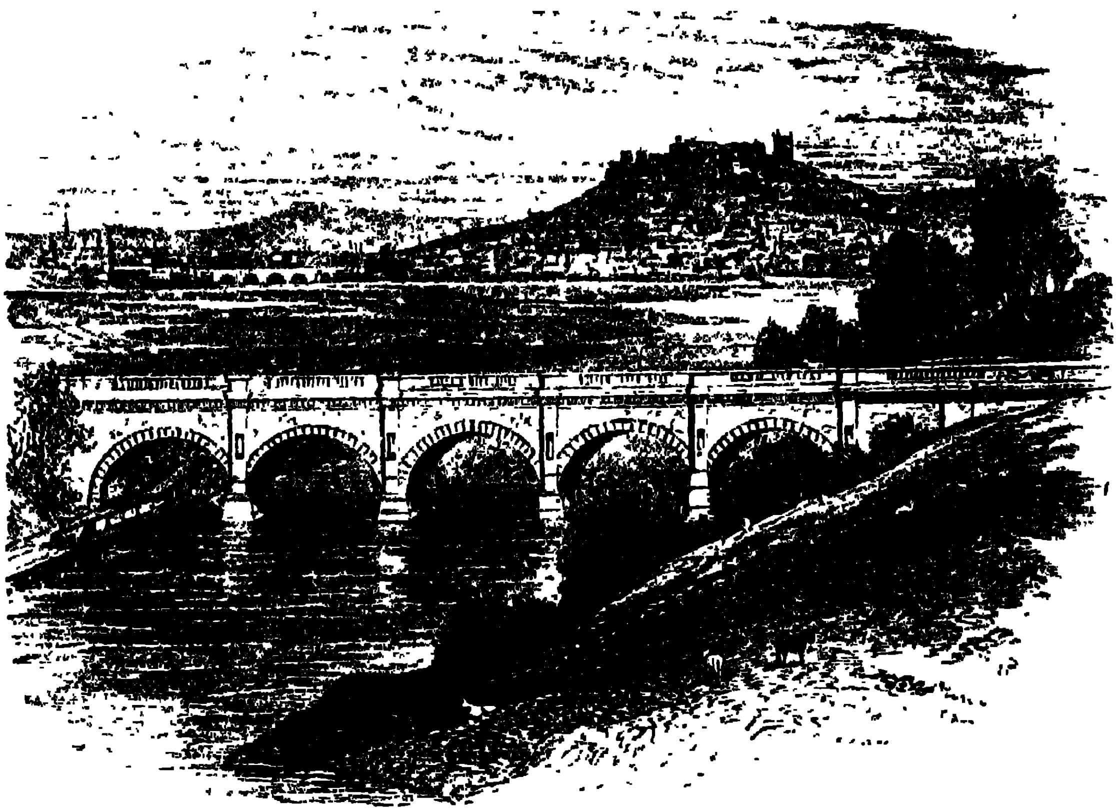
Another important line of navigation, on which Mr. Rennie was shortly after engaged, was the Rochdale Canal, projected for the purpose of opening up a direct water communication between the manufacturing districts of West Yorkshire and South Lancashire, to avoid the circuitous route of the Leeds and Liverpool Canal. The main line extended from the Duke of Bridgewater's Canal at Manchester, by Rochdale and Todmorden, to the river Calder at Sowerby Bridge, a distance of 31½ miles, with a branch to join the Leeds and Liverpool Canal at Wanless, and other branches to Bury and Bolton. From the rugged nature of the country over which the canal had to be carried—having to be lifted from lock to lock over the great mountain-ridge known as "the backbone of England"—few works have had greater physical obstacles to encounter than this between Rochdale and Todmorden.

Locks on the Rochdale Canal. [By Percival Skelton, after his original Drawing.]

A little before the traveller by railway enters the tunnel near Littleborough, on his way between Manchester and Leeds, he can discern the canal mounting up the rocky sides of the hills until it is lost in the distance; and as he emerges from the tunnel at its other end, it is again observed descending from the hill-tops by a flight of locks down to the level of the railway. In crossing the range at one place, a stupendous cutting, fifty feet deep, had to be blasted through hard rock. In other places, where winds along the face of the hill, it is overhung by precipices.

On the Yorkshire side, at Todmorden, the valley grows narrower and narrower, overhung by steep, often almost perpendicular rocks of millstone-grit, with space, in many parts, for only the water-way, the turnpike road, and the little river Calder in the bottom of the ravine. At some points, where space allowed, there were mills and manufacturing establishments jealous of their water-supply, which the engineer had carefully to avoid. It was also necessary to provide against the canal being swept away by the winter's floods of the Calder, which rushed down with immense violence from Blackstone Edge. Large reservoirs had to be carefully contrived to store up water against summer droughts, for the purposes of the navigation, as well as to compensate the numerous mills along the valley below. One of these, fourteen feet deep, was dug in a bog on Blackstone Edge, and others, of large dimensions, were formed at various points along the hill-route. But as these expedients were of themselves insufficient, powerful steam-engines were also erected to pump back the lockage water into the canal above, as well as into side-ponds near the locks to serve for reservoirs, and thus economise the supply to the greatest extent.

No more formidable difficulties, indeed, were encountered by George Stephenson, in constructing the railway passing by tunnel under the same range of hills, than were overcome by Mr. Rennie in carrying out the works of this great canal undertaking. The skill and judgment with which he planned them reflected the greatest credit on their designer; and whoever examines the works at this day—even after all that has been accomplished in canal and railway engineering—will admit that the mark of a master's hand is unmistakably stamped upon them. The navigation was completed and opened on the 21st of December, 1804; and we need scarcely add that it proved of immense service to the trade of Yorkshire and Lancashire,—bringing important manufacturing districts into easy and economical connection with each other, enabling cheap fuel to be brought to the doors of the population of the valleys along which it passed, placing them in direct communication with the markets of Manchester and Liverpool, and, through the latter port, opening up a water road to the world at large.



Lune Aqueduct, near Lancaster. By Percival Skelton, after his original Drawing.]

The Lancaster Canal was another enterprise conducted by Mr. Rennie in the same neighbourhood. A navigable communication between the coal-fields near Wigan and the lime districts about Lancaster, Burton, and Kendal, connecting these towns also with the intervening country as well as with Liverpool, Manchester, and the towns of South Lancashire, had long been regarded as an object of importance. A survey had been made by Mr. Brindley as early as 1772, but nothing further was done until some twenty years later, when a company was formed, with Mr. Rennie as engineer. The line surveyed by him commences near Wigan, and proceeds northward by Chorley, Preston, and Garstang, to Lancaster, where, skirting the east side of the town, and crossing the Lune by a noble aqueduct, it then passes by Haughbridge to its northern terminus at Kendal; the total length of the main line being 75¼ miles, and the branches two miles more. The aqueduct over the Lune is the principal architectural work on the canal, consisting of five semicircular arches of 75 feet span each; the soffits being 50 feet, and the surface of the canal 62 feet above the average level of the river. The total length of the aqueduct—which forms a prominent feature in the landscape—is 600 feet. The whole is built of hard sandstone, the masonry being in imitation of rock-work, the top surmounted by a handsome Doric cornice and balustrade. It exhibits, in fine combination, the important qualities of strength, durability, and elegance in design; and even at this day it will bear a favourable comparison with the best works of its kind in the kingdom.

Mr. Rennie continued throughout his life to be extensively consulted as a canal engineer.* Though navigations were then mostly valued for purposes of internal communication, he seems early to have appreciated the uses of the railway, if not as a substitute for them, at least as an adjunct. Thus, when laying out a new branch of the Grand Trunk Canal at Henley, in the Potteries, he recommended the addition of a short descending railway, connecting the navigation directly with the manufactories at Burslem. Referring to this method of communication, he observed that the railroad "would form a quick and cheap mode of carrying goods. Indeed," he added, "I do not know a cheaper or better, and, in my opinion, it might be substituted with great advantage for the branch canal in question. I have therefore to submit whether, as a matter worthy of the consideration of the proprietors, this branch might not be saved, and a railroad substituted in its place." This report was written, be it observed, early in 1797, long before railroads had been introduced; and the suggestion affords striking evidence of Mr. Rennie's sagacity in so early detecting and appreciating the advantages of this new method of communication.

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* The following canal works of Mr. Rennie may be mentioned:—The Aberdeen and Inverurie, 12 miles long, laid out and constructed by him in 1796-7; the Calder Reservoirs and improvement of the Trent and Mersey Canal at Rudyard Valley, near Leek, 1797-8; a branch of the Grand Trunk Canal to Henley, with a railway connecting it with the manufactories. He also made elaborate reports on the Leominster Canal (1798); on the Chelmer and Blackwater Navigation; Somersetshire and Dorsetshire Canal; Horncastle Navigation; River Foss Navigation; Polbrook Canal (1799); Rotherhithe and Croydon; Thames and Medway (1800); and River Lea Navigation (1801). Among the works surveyed by him, but which were not carried out, were these: a canal through the Weald of Kent (1802-3); a ship-canal between the Thames and Portsmouth (1803); a ship-canal between the Medway and Portsmouth (1810); a ship-canal from Chichester Harbour to Chichester (1801); and a ship-canal from Bristol to the English Channel (1811). He was also employed by the Gloucester and Berkeley Canal Company, the Birmingham Canal Company, and the Leeds and Liverpool Canal Company, as their consulting en

In 1802 Mr. Rennie was requested to examine the works of the Royal Canal of Ireland. The origin of this project was curious. The Grand Canal had already been formed to connect the navigation of the Liffey with that of the Shannon near Banagher; and though enormous blunders had marred its construction, and its cost had consequently been excessive, the traffic upon it was so great as nevertheless to render it exceedingly profitable to its proprietors.

The managing committee consisted for the most part of persons of high rank, but amongst them was a retired shoemaker, who had invested a very large sum in the undertaking, and made himself exceedingly busy in its concerns. Offence seems to have been taken at this person; and his meddling in various matters, without authority, caused a rupture between him and the other members of

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gineer; and various important improvements in these navigations were carried out by his advice and under his superintendence.

the committee. They thwarted him at every turn, outvoted him, snubbed him, and "sent him to Coventry." Vowing revenge, the shoemaker threw up his seat at the board, and, on parting with his colleagues, said to them, "You may think me a very insignificant person, but I will soon show you the contrary. I will sell out forthwith, start a rival canal, and carry all the traffic." The threat was, of course, treated with contempt, and the shoemaker was laughed out of the board-room.

But the indignant man set to work with energy, got up a company, laid down a line of navigation from Dublin to the Shannon near Longford, passing by Mullingar; he secured the support of the landed gentry through whose property the line passed, and eventually succeeded in obtaining an Act of Parliament authorising the construction of the Royal Canal of Ireland. The works were begun with great eclat; but, before they had proceeded far, it was found that the levels were entirely wrong, and there were numerous difficulties to be overcome, for which no provision had been made.

Then it was that Mr. Rennie was called in, and found the whole concern in confusion; the works at a standstill in many places, in bogs, in cuttings, in embankments, and in limestone rocks, and the proprietors involved in almost endless claims for compensation. He found it necessary to resurvey the whole line and to alter the plans in many essential respects; after which the works proceeded. It proved to be a work of an extraordinary character as regarded the difficulties, mostly unnecessary, which had been encountered in its construction; as respected the beneficial results to the proprietors, it proved an almost total failure.

The shoemaker, no doubt, had his revenge upon his former associates, inflicting great injury upon the Grand Canal by the diversion of much of its traffic; but he accomplished this at a terrible sacrifice to many, and at the almost total loss of his own fortune.

CHAPTER V.

MR. RENNIE'S DRAINAGE OF THE LINCOLN AND CAMBRIDGE FENS.

NOTWITHSTANDING all that had been done for the drainage of the Fens, as described in the early part of this work, large districts of reclaimable lands in Lincoln still lay waste and unprofitable. As early as 1789, Mr. Rennie's attention was drawn to the drowned state of the rich low-lying lands to the south of Ely. He then recommended the application of Watt's steam-engine to pump the water out of the Botteshaw and Soham Fens, which contained about five thousand acres of what was commonly called "rotten land." But the Fen men would not have the steam-engine. They were too much prejudiced in favour of drainage by windmills, as practised in Holland. It was not until many years after, that his recommendation was adopted and the steam-engine was employed to pump the water from the low-lying swamps which could not otherwise be cleared. The results were so successful, that the same agency became generally employed for the purpose, not only in England but in Holland itself, where the forty-five thousand acres of Haarlemer Meer have since been effectually drained by the application of the steam-engine.

One of the most important works of thorough drainage carried out by Mr. Rennie, was in that extensive district of South Lincolnshire which extends along the south verge of the Wolds, from near the city of Lincoln eastward to the sea. It included Wildmore Fen, West Fen, and East Fen, and comprised about seventy-five thousand acres of land which lay under water for the greater part of each year, and was thus comparatively useless either for grazing or tillage. The only crop grown in the fens was tall reeds, which were used as thatch for houses and barns, and even for churches.

The river Witham, which flows by Lincoln, had been grievously neglected and allowed to become silted up,—its bottom being in many places considerably above the level of the land on either side. Hence, bursting of the banks frequently occurred during floods, causing extensive inundation of the lower levels,—only a small proportion of the flood-waters being able to force their way to the sea.

The wretched state of the land may be inferred from the fact that, about seventy years since, a thousand acres in Blankney Fen, constituting part of "the Dales"—now one of the most fertile parts of the district between Lincoln and Tattershall—were let annually by public auction at Horncastle, and the reserved bid was only 10*l.* for the entire area! * It is stated that, about the middle of last century, there were not two houses in the whole parish of Dogdyke communicable with each other during the winter, except by boat; this being also the only means by which the Fen-slodgers could get to church. Hall, the Fen Poet, speaks of South Kymo, where he was born, as a district in which, during the winter season, nothing was to be seen—

"But naked flood for miles and miles."

The entire breadth of Lincolnshire north of Boston often lay under water for months together:—

"'Twixt Frith bank and the wold side bound,
I question one dry inch of ground.
From Lincoln all the way to Bourne,
Had all the tops of banks been one,
I really think they all would not
Have made a twenty acre spot."

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* 'Journal of Royal Agricultural Society,' 1847, vol. viii. p. 124.

Until as recent a date as forty years back, the rich and fertile district of Waldersea, about eight thousand acres in extent, was, as its name imports, a sea in winter. Well might Roger Wildrake describe his paternal estate of "Squattlesea Mere" as being in the "moist county of Lincoln!"

Arthur Young visited this district in 1793, and found the freeholders of the high lands adjoining Wildmore and West Fens depasturing their sheep on the drier parts during the summer months; but large numbers of them were dying of the rot. "Nor is this," he adds, "the only evil; for the number stolen is incredible. They are taken off by whole flocks, as so wild a country (whole acres being covered with thistles and nettles four feet high and more), nurses up a race of people as wild as the fen." The few wretched inhabitants who contrived to live in the neighbourhood for the most part sheltered themselves in huts of rushes or lived in boats. They were constantly liable to be driven out of their cabins by the waters in winter, if they contrived to survive the attacks of the ague to which they were perennially subject.*

The East Fen was the worst of all. It was formerly a most desolate region, though it now presents probably the richest grazing land in the kingdom. Being on a lower level than the West and Wildmore Fens, and the natural course of the waters to the sea being through it to Wain-

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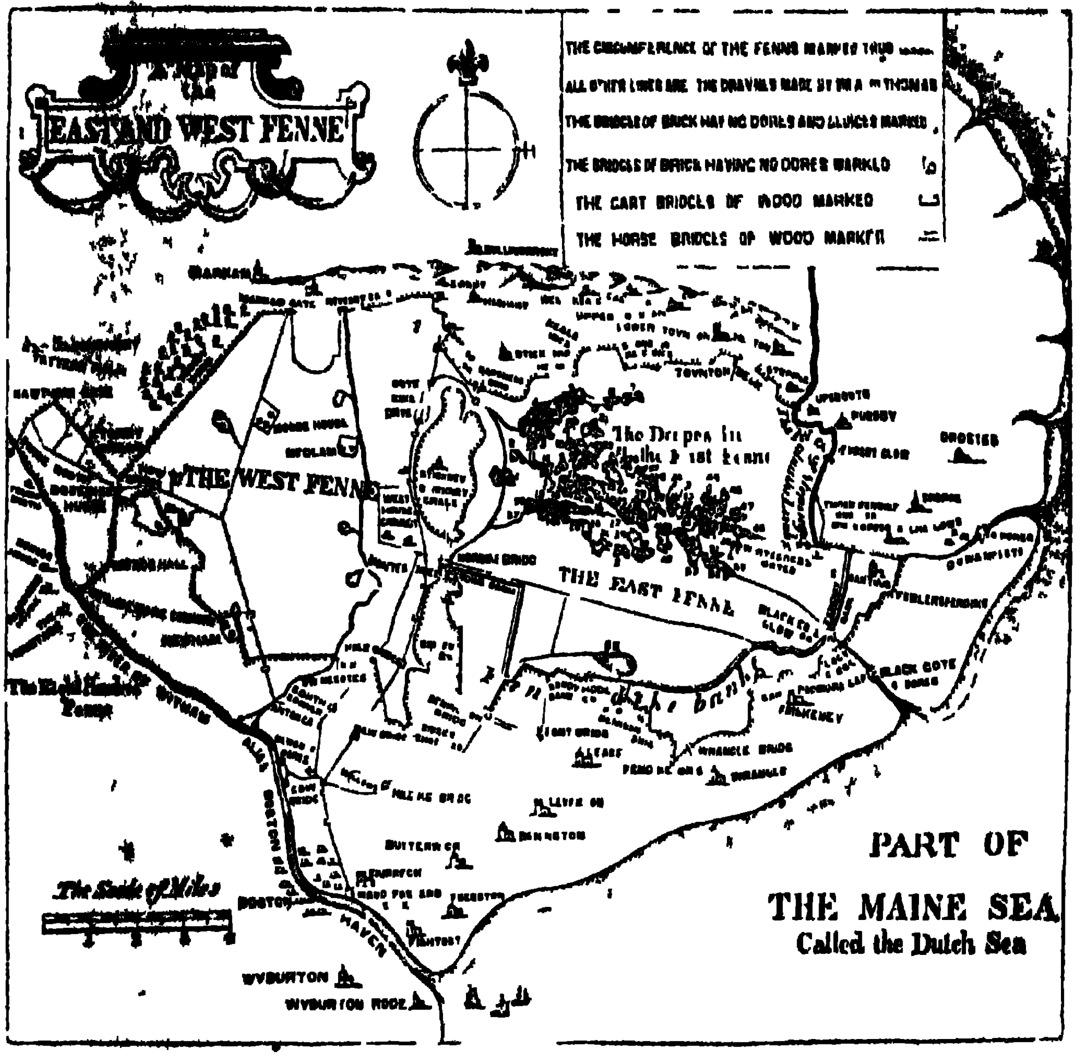
* A writer in an old number of the 'Universal Magazine' (published in 1773) describes a conversation with a cadaverous-looking man whom he encountered in the Fens, and condoled with on his forlorn and meagre appearance. The man rejoined, that he had never been better since he had buried the first of his nine wives. "Nine wives?" "Yes, nine wives!" was the reply. The man explained that the Fen men were accustomed to seek their wives in the upland country, selecting those who had a little money; and as living in the Fens was certain death to strangers during the fever season, many of the Fen men thus contrived to accumulate a good deal of money. But the Fen districts have long since ceased to possess this peculiar advantage, for they are now as healthy as the upland districts themselves.

[illegible] Haven, it was in a much more drowned state than those to the westward. About two thousand acres were constantly under water, summer and winter. One portion of it was called Mossberry or Cranberry Fen, from the immense quantities of cranberries it produced. A great


A Map of the
EAST AND WEST FENNE
THE CIRCUMFERENCE OF THE FENNS MARKED THUS
ALL OTHER LINES ARE THE DRAYNES MADE BY MR A THOMAS
THE BRIDGES OF BRICK HAVING DORES AND SLUICES MARKED
THE BRIDGES OF BRICK HAVING NO DORES MARKED
THE CART BRIDGES OF WOOD MARKED
THE HORSE BRIDGES OF WOOD MARKED
THE WEST FENNE
The Deepes in the East Fenne
THE EAST FENNE
BOSTON
WYBURTON
HAVEN
The Scale of Miles
PART OF
THE MAINE SEA
Called the Dutch Sea

The Lincolnshire Fens. [Before their Drainage by Mr. Rennie.]

part of the remainder of the East Fen consisted of shaking bog, so treacherous and so deep in many places that only a desperate huntsman would venture to follow the fox when he took to it, and then he must needs be well acquainted with the ground.

Matters were in this state when Sir Joseph Banks, then

President of the Royal Society, endeavoured to stir up the landowners to undertake the drainage of the district. He was the proprietor of a good estate at Revesby, near Tattershall; and his mansion of Abbot's Lodge, standing on an elevated spot, overlooked the East and West Fens, of which it commanded an extensive view. Sir Joseph spent a portion of every year at Revesby, as he did at his other mansions, leaving each at special times appointed beforehand, almost with the regularity of clockwork. He was a popular and well-known man, jolly and good-humoured, full of public spirit, and, though a philosopher, not above taking part in the sports and festivities of the neighbourhood in which he resided. While Sir Joseph lived at Revesby he used to keep almost open house, and a constant succession of visitors came and went—some on pleasure, some on friendship, and some on business.

The profuse hospitality of the place was enjoyed not less by the postilions and grooms who drove thither the baronet's guests, than by the visitors themselves; and it was esteemed by the hotel postboys a great privilege to drive a customer to Revesby. On one occasion, when Mr. Rennie went to dine and sleep at the Lodge, he took an opportunity of saying to the principal butler that he hoped he would see to his postboy being kept *sober*, as he wished to leave before breakfast on the following morning. The butler replied, with great gravity, that he was sorry he could not oblige Mr. Rennie, as the same man had left Revesby sober the last time he was there, but only on condition that he might be allowed to get drunk the next time he came. "Therefore," said the butler, "for the honour of the house, I must keep my word; but I will take care that you are not delayed for the want of horses and a postboy." The butler was as good as his word: the man got drunk, the honour of Revesby was saved, and Mr. Rennie was enabled to set off in due time next morning.

From an early period Sir Joseph Banks entertained the design of carrying out the drainage of the extensive fen lands lying spread out beneath his hall window, and making them, if possible, a source of profit to the owners, as well as of greater comfort and better subsistence for the population. Indeed, the reclamation of these unhealthy wastes became quite a hobby with him; and when he could lay hold of any agricultural improver, he would not let him go until he had dragged him through the Fens, exhibited what they were, and demonstrated what fertile lands they might be made. When Arthur Young visited Revesby about 1799, Sir Joseph immediately started his favourite topic. "He had the goodness," says Young, in his Report on Lincolnshire, "to order a boat, and accompanied me into the heart of East Fen, which had the appearance of a chain of lakes, bordered by great crops of reed."

Sir Joseph was a man of great public spirit and determination: he did not allow the matter to sleep, but proceeded to organize the ways and means of carrying his design into effect. His county neighbours were very slow to act, but they gradually became infected by his example, and his irresistible energy carried them along with him. The first step taken was to call meetings of the proprietors in the several districts adjoining the drowned and "rotten lands." Those of Wildmore Fen met at Horncastle on the 27th of August, 1799, and resolutions were adopted authorizing the employment of Mr. Rennie to investigate the subject and report to a future meeting.

One reason, amongst others, which weighed with Sir Joseph Banks in pressing on the measure was the scarcity of corn, which about that time had risen almost to a famine price. There was also great difficulty in obtaining supplies from abroad, in consequence of the war which was then raging. Sir Joseph entertained the patriotic opinion that the best way of providing for the exigency was to extend the area of our English food-ground by the reclamation of the waste lands; and hence his determination to place under tillage, if possible, the thousands of acres of rich soil, equal to the area of some English counties, lying under water almost at his own door. A few years' zealous efforts, aided by the skill of the engineer, produced such results as amply to justify his anticipations, and proved his judgment to be as wise as his patriotism was beneficent.

The manner in which Mr. Rennie proceeded to work out the problem presented to him, was thoroughly characteristic of the man. Most of the drainage attempted before his time was of a very partial and inefficient character. It was enough if the drainers got rid of the surplus water anyhow, either by turning it into the nearest river, or sending it in upon a neighbour. What was done in one season was usually undone in the next. The ordinary drainer did not care to look beyond the land immediately under his own eyes. Mr. Rennie's practice, on the contrary, was founded on a large and comprehensive view of the subject. He was not bounded by the range of his vision, but took into account the whole contour of the country. He had to consider the rainfall of the districts through which his drains were to run, as well as that of the central counties of England, whose waters flowed down upon the Fens; the requirements of the lands themselves as regarded their irrigation and navigation; and, finally, the most effectual method not only of removing the waters from particular parts, but of providing for their effectual discharge by proper outfalls into the sea.

What was the problem now to be solved by our engineer? It was how best to carry out to sea the surplus waters of a district extending from the eastern coast to almost the centre of England. Various streams descending from the Lincolnshire wolds flowed through the level, whilst the Witham brought down the rainfall not only of the districts to the north and east of Lincoln, but of a large part of the central counties of Rutland and Leicester. It was, therefore, necessary to provide for the clear passage of these waters, and also to get rid of the drainage of the Fens themselves, a considerable extent of which lay beneath the level of the sea at high water.

It early occurred to Mr. Rennie that, as the waters of the interior for the most part came from a higher level, their discharge might be provided for by means of distinct drains, and prevented from at all mingling with those of the lower lying lands. But would it be possible to "catch" these high land waters before their descent upon the Fens, and then to carry them out to sea by means of independent channels? He thought it would; and with this leading idea in his mind he proceeded to design his plan of a great "catch-water drain," extending along the southern edge of the Lincolnshire wolds.

But there were also the waters of the Fens themselves to be got rid of, and how was this to be accomplished? To ascertain the actual levels of the drowned lands, and the depth to which it would be necessary to carry the outfall of his drains into the sea, he made two surveys of the district—the first in October 1799, and the second in March 1800—thus observing the actual condition of the lands both before and after the winter's rains. At the same time he took levels down to the sea outfalls of the existing drains and rivers. He observed that the Wash, into which the Fen waters ran, was shallow and full of shifting sands and silt. He saw that, during winter, the rivers were loaded with alluvial matter held in suspension, and that, at a certain distance from their mouths, the force of the inland fresh and the tidal sea waters neutralized each other; and that there a sort of stagnant point was formed, at which the alluvium was no longer held in suspense by the force of the current. Hence it became precipitated in the channels of the rivers, and formed banks or bars in the Wash outside their mouths, which proved alike obstructive to drainage and navigation.

It required but little examination to detect the utter inadequacy of the existing outfalls to admit of the discharge of the surplus waters of so extensive a district. The few sluices which had been provided had been badly designed and imperfectly constructed. The levels of the outfalls were too high, and the gowts and sluices too narrow, to accommodate the drainage in flood-times. These outfalls were also liable, in dry summers, to become choked up by the silt settling in the Washes; and when a heavy rain fell, down came the waters from the high lands of the interior, and, unable to find an outlet, they burst the defensive banks of the rivers, and an amount of mischief was thus done which the drainage of all the succeeding summer failed to repair.

Accordingly, the next essential part of Mr. Rennie's scheme was the provision of more effectual outfalls; with which object he designed that they should be cut down to the lowest possible level of low water, whilst he arranged that at the points of outlet they should be mounted with strong sluices, opening outwards; so that, whilst the fresh waters should be allowed freely to escape, the sea should be valved back and prevented flowing in upon the land. The third and last point was to provide for the drainage of the Fen districts themselves by means of proper cuts and conduits for the voidance of the Fen waters.

Such were the general conclusions formed by Mr. Rennie after a careful consideration of the circumstances of the case, which he embodied in his report to the Wildmore Fen proprietors * as the result of his investigations. The two great features of his plan, it will be observed, were: (1) his intercepting or catchwater drains, and (2) his cutting down the outfalls to lower levels than had ever before been proposed. Simple though his system appears, now that its efficacy has been so amply proved by experience, it was regarded at the time as a valuable discovery in the practice of fen-draining, and indeed it was nothing less.

There were, however, plenty of detractors, who alleged that it was nothing of the kind. Any boy, they said, who

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* Report, dated the 7th of April, 1800.

has played at dirt-pies in a gutter, knows that if you make an opening sufficiently low to let the whole contained water escape, it will flow away. It was the story of Columbus and the egg over again. It was quite true; and yet no one had ever proposed or attempted Rennie's plan; and it cost him many years of arguing, illustration, and enforcement, before he could induce the Fen-drainers of other districts to adopt the same simple but thoroughly scientific method by which he had effectually drained the Lincolnshire Fens. And even to this day there are whole districts in which the stubborn obstinacy of ignorant obstructives still continues to stand in the way of its introduction. The Wildmore Fen proprietors, however, had the advantage of being led by a sagacious, clear-seeing man in Sir Joseph Banks, who cordially supported the adoption of the plan with all the weight of his influence, and Mr. Rennie was eventually empowered to carry it into execution.

In laying out the works, he divided them according to their levels, placing Wildmore and West Fen in one plan, and East Fen in another. In draining the former, the outlet was made by Anton's Gowt, about two miles and a half above Boston, and by Maud Foster, a little below that town. But both of these, being found too narrow and shallow, were considerably enlarged and deepened, and provided with double sluices and lifting gates: one set pointing towards the Witham, in order to keep out the tides and river-floods; the other to the land, in order to prevent the water in summer from draining too low, and thereby hindering navigation as well as the due irrigation of the lands. An extensive main drain was also cut through the Wildmore and West Fens to the river Witham, about twenty-one miles long and from eighteen to thirty feet wide, the bottom being an inclined plane falling six inches in the mile.

The level of the East Fen being considerably lower than that of the Fens to the westward, it was necessary to provide for its separate drainage, but on precisely the same principles. From the levels which were taken, it appeared that the bottom of "the Deeps," which formed part of the East Fen, was only two feet six inches above the sill of Maud Foster Sluice, thirteen miles distant; whereas its highest parts were but eight feet above the same point, giving a fall of only an inch and eight-tenths per mile at low water of neap tides. From some of the more distant parts of the same Fen, sixteen miles from the outfall, there would only have been a fall of five-tenths of an inch per mile at low water. It was clear, therefore, that even the higher levels of the East Fen could not be effectually drained by the outfall at Anton's Gowt or Maud Foster; and hence arose the necessity for cutting an entirely separate main drain, with an outfall at a point in the Wash outside the mouth of the river Witham.*

This east main cut, called the Hobhole Drain, is about eighteen miles long and forty feet wide, diminishing in breadth according to its distance from the outfall; the bottom being an inclined plane falling four inches in the mile towards the sluice at Hobhole in the Wash. This drain is an immense work, defended by broad and lofty embankments extending inland from its mouth, to prevent the contained waters flooding the surrounding lands. It is protected at its sea outlet by a strong sluice, consisting of three openings of fifteen feet each. When the tide rises, the gates, acting like a valve, are forced back and hermetically closed; and when it falls, the drainage waters, which have in the mean time accumulated, force open the gates again, and the waters flow into the sea down to the level of low water. A connection was also formed between the main drains emptying themselves at Maud Foster (three miles higher up the Witham) and the Hobhole Drain, the flow being regulated by a gauge; so that, during heavy floods, not only the low land waters of the East Fen districts were effectually discharged at Hobhole, but also a considerable portion of the drainage of the West and Wildmore Fens.

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* See the Map in vol. i. of the "Fens as Drained in 1830;" p. 51.

An essential part of the scheme was the cutting of the catchwater drains, which were carried quite round the base of the high lands skirting the Fens; beginning with a six-feet bottom, and widening out towards their embouchures to sixteen feet. The principal work of this kind commenced near Stickney, and was carried eastward towards Wainfleet, to near the Steepings river. It was connected at Cowbridge with the main Hobhole Drain, into which the high land waters brought down by the catchwater drain were thus carried, without having been allowed, until reaching that point, to mix with the Fen drainage at all.

It would be tedious to describe the works more in detail; and perhaps the outline we have given, aided by the maps of the district, will enable the reader to understand the leading features of Mr. Rennie's comprehensive design. The works were necessarily of a very formidable character, the extent of the main and arterial drains cut during the seven or eight years they were under execution being upwards of a hundred miles. They often dragged for want of funds, and encountered considerable opposition in their progress; though the wisdom of the project was in all respects amply justified by the result.*

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* The following letter, written by a Lincolnshire gentleman, in January, 1807, appears in the 'Farmer's Magazine' of February in that year:—"Our fine drainage works begin now to show themselves, and in the end will do great credit to Mr. Rennie, the engineer, as being the most complete drainage that ever was made in Lincolnshire, and perhaps in England. I have been a commissioner in many drainages, but the proprietors never would suffer us to raise money sufficient to dig deep enough through the old enclosures into the sea before; and, notwithstanding the excellency of Mr. Rennie's plan, we have a party of uninformed people, headed by a little parson and magistrate, who keep publishing letters in the newspapers to stop the work, and have actually petitioned Sir Joseph Banks, the lord of the manor, against it; but he answered them with a refusal, in a most excellent way. . . . I think Mr. Rennie's great work will promote another general improvement here, which is, to deepen and enlarge the river Witham from the sea, through

When the drainage of Wildmore and West Fens was finished, forty thousand acres of valuable land were completely reclaimed, and in a few years yielded heavy crops of grain. East Fen was attacked the last, the difficulties presented by its formidable chain of lakes being by much the greatest; but the prize also was by far the richest. When the East Fen waters were drained off, the loose black mud settled down into fertile soil. Boats, fish, and wildfowl disappeared, and the plough took their place. After being pared and burnt, the land in the East Fen yielded two and even three crops of oats in succession, of not less than ten quarters to the acre.

The cost of executing the drainage had no doubt been very great, amounting to about 580,000*l.* in all, inclusive of expenditure on roads, &c.; against which had to be set the value of the lands reclaimed. In 1814 Mr. Anthony Bower, surveyor and valuer, estimated their improved rental at 110,561*l.*; and allowing five per cent. on the capital expended on the works, we thus find the increased net value of the drained lands to be not less than 81,000*l.* per annum, which, at thirty years' purchase, gives a total increased value of nearly two millions and a half sterling! *

It was a matter of great regret to Mr. Rennie that his

Boston and Lincoln to the Trent, so as to admit of a communication for large vessels, as well as laying the water so much below the surface of the land as to do away with the engines. We have got an estimate, and find the cost may be about 100,000*l.*"

* Mr. Bower's estimate was as follows:—

Land reclaimed in the East Fen ..	12,664 acres worth	40*s.* per ann.	£25,328
„ „ West Fen ..	17,044 „	50*s.* „	42,610
„ „ Wildmore ..	10,773 „	42*s.* „	22,623
Adjoining low lands improved ..	20,000 „	20*s.* „	20,000
Total acreage of improved and drained lands..	60,481	Annual value	£110,561
Less capital expended on drainage .			
„ „ roads, &c. .			
	£580,705 at 5 per cent. .		

Which at 30 years' purchase gives £2,445,780.

design was not carried out as respected the improved outfall of the Witham. It was an important part of his original plan that a new and direct channel should be cut for this river from Boston down to deep water at Clayhole, where the tide ebbed out to the main sea level, and there was little probability of the depth being materially interfered with by silting for many years to come. This new channel would have enabled all the waters—low land as well as high land—to be discharged into the sea with the greatest ease and certainty. It would also have completely restored the navigation of the river, which had become almost entirely lost through the silting up of its old winding channel.

But the river Witham was under the jurisdiction of the corporation of Boston, who were staggered by the estimated cost of executing the proposed works, though it amounted to only 50,000*l*. Accordingly, nothing was done to carry out this part of the design, and the channel continued to get gradually worse, until at length it was scarcely possible even for small coasters to reach Boston Quay. As late as the year 1826 the water was so low that little boys were accustomed to amuse themselves by wading across the river below the town even at high water of neap tides. The corporation were at last compelled to bestir themselves to remedy this deplorable state of affairs, and they called in Sir John Rennie to advise them in their emergency. The result was, that as much of the original plan of 1800 * was carried out as the state of their funds would permit: the lower part of the channel was straightened, and the result was precisely that which the engineer had more than thirty years before anticipated. The tide returned to the town, the shoals were removed, and vessels drawing from twelve to fourteen feet water could again come up to Boston Quay at spring tides.

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* In his admirable Report dated the 6th October, 1800, Mr. Rennie pointed out that the lines of direction in which the rivers Welland and Witham entered the Wash tended to the silting-up of the channels of both, and he suggested that the two river outlets should be united in one, and diverted into the centre of the Wash, at Clayhole, which would at the same time greatly increase the depth, and enable a large area of valuable land to be reclaimed for agricultural purposes. This suggestion has since been elaborated by Sir John Rennie, whose plan of 1837, when fully carried out, will have the effect of greatly improving the outfalls of all the rivers entering the great Wash—the Ouse, the Nene, the Welland,

Mr. Rennie was equally successful in carrying out drainage works in other parts of the Fens, on the same simple but comprehensive principles.* He thus drained the low lands of Great Steeping, Thorpe, Wainfleet All Saints, Forsby, and the districts thereabout, converting the Steepings river into a catchwater drain, and effectually reclaiming a large acreage of highly valuable land. He was also consulted as to the better drainage of the North Level, the Middle Level, South Holland, and the Great Bedford Level; and his valuable reports on these subjects, though not carried out at the time, for want of means, or of public spirit on the part of the landowners, laid the foundations of a course of improvement which has gone on until the present day. It is much to be regretted, that his plan of 1810, for the drainage of the Great Level, by means of more effectual outfalls and a system of

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and the Witham—and the drainage of the low level lands depending upon them, comprising above a million of acres, and ultimately gaining from the Wash between 150,000 and 200,000 acres of rich new land, or equal to the area of a good-sized county. In the Wash of the Nene, called Sutton Wash, 4000 acres have already been reclaimed after this plan—the land, formerly washed by the sea at every tide, being now covered with rich corn-fields and comfortable farmsteads. It was at this point that King John's army was nearly destroyed when crossing the sands before the advancing tide.

* Among other important works of the same kind executed by Mr. Rennie, but which it would be tedious to describe in detail, was the reclamation (in 1807) of 25,000 acres of fertile land in the district of Holderness, near Hull. He was extensively employed to embank lands exposed to the sea, and succeeded (in 1812) in effectually protecting the thirty miles of coast extending from Wainfleet to Boston, and thence to the mouths of the rivers Welland and Glen. Two years later (in 1814) he, in like manner, furnished a plan, which was carried out, for protecting the Earl of Lonsdale's valuable marsh land on the south shore of the Solway Frith.

intercepting catchwater drains, was not carried out; for there is every reason to believe that it would have proved as completely successful as his drainage of the Fens of Lincolnshire. The only part of his scheme that was executed was the Eau Brink Cut, for the purpose of securing a more effectual outfall of the river Ouse into the Wash near King's Lynn.

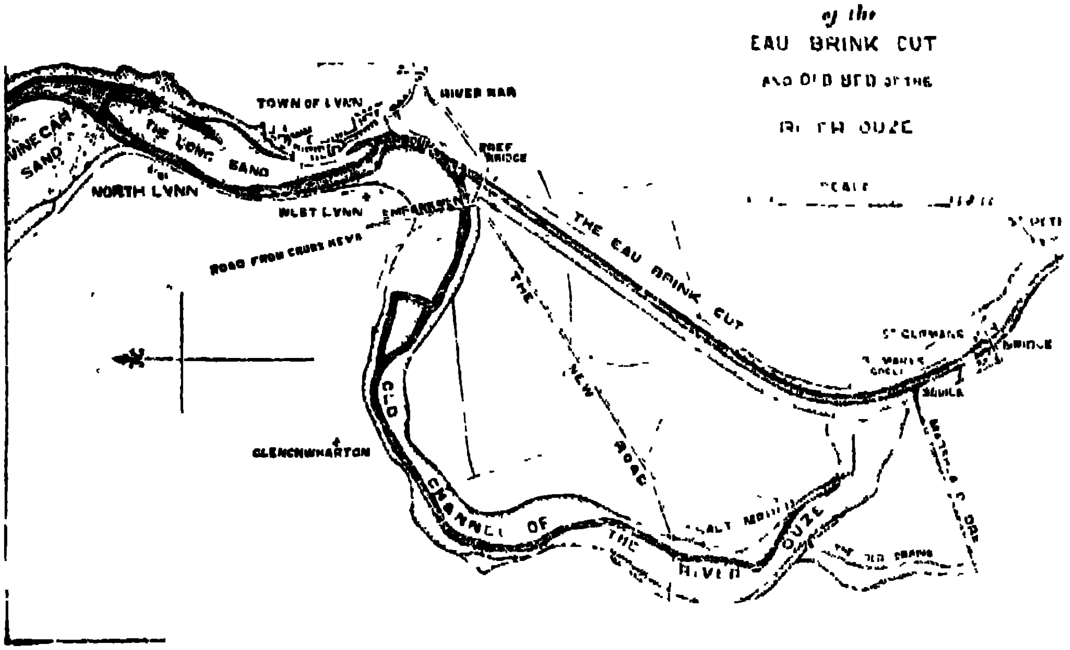
The necessity for this work will be more clearly understood when we explain the circumstances under which its construction was recommended. It will be observed from the map of the Fen district (vol. i. p. 32), that the river Ouse flows into the shallows of the Wash near the town of King's Lynn, where it is charged with the waters of the Great Bedford Level as well as of Huntingdon, Bedford, and Cambridge, and of the high lands of the western parts of Norfolk and Suffolk. Immediately above Lynn, the old river made an extensive bend of about five miles in extent, to a point called German's Bridge. This channel was of very irregular breadth, and full of great sand beds which were constantly shifting. In some places it was as much as a mile in width, and divided into small streams, which varied according as the tidal or the fresh waters were, for the time being, most powerful. During floods, the flow of the river was so much obstructed that the waters could not possibly get away out to sea during the ebb, so that at the next rise of the tide they were forced back into the interior, and thus caused serious inundations in the surrounding country.

Much good land which had formerly been productive, had become greatly deteriorated, or was apparently lost for agricultural purposes. Some districts were so constantly flooded, and others were so wet, that they were rapidly returning to their original state of reeds and sedge. In the neighbourhood of Downham Eau, the harvest-men were, in certain seasons, obliged to stand upon a platform to reap their corn, which was carried to and from the drier parts in boats; and some of the farmers, in like manner rowed through their orchards in order to gather the fruit from the trees. A large portion of Littleport Fen, in the South Level, was let at a shilling an acre, and, in the summer-time, cattle were turned in amongst the reed and "turf-bass," and were not seen again for weeks. In Marshland Fen, the soil was so soft that wooden shoes, or flat boards, were nailed on the horses' feet over the iron ones, to prevent them from sinking into the soil.

The fresh waters were in this way penned up within the land to the extent of about seven feet; and over an extensive plain, such as the Bedford Level, where a few inches of fall makes all the difference between land drained and land drowned, it is clear how seriously this obstruction of the Ouse outfall must have perilled the agricultural operations of the district. Until, therefore, this great impediment to the drainage of the Level could be removed, it was clear that no inland works could be of any permanent advantage. The remedy which Mr. Rennie proposed was, to cut off the great bend in the Ouse by making a direct new channel from Eau Brink, near the mouth of Marshland Drain, to a point in the river a little above the town of Lynn, as shown in the plan on the opposite page. The cut was to be about three miles in length, and of sufficiently capacious dimensions to contain the whole body of the river. By thus shortening the line of the stream, Mr. Rennie calculated that the channel would be kept clear of silt by the greater velocity of the current, and that the fresh waters would at the same time be able to force their way out to sea without difficulty.

An Act was accordingly obtained, enabling the Eau Brink to be cut; but several years passed before any steps were taken to carry out the works. They were not actually begun until the year 1817, when Mr. Rennie was formally appointed the chief engineer. After about four years' labour the cut was finished and opened, and its immediate effect was to give great relief to the whole of the district watered by the Ouse. An extra fall of not less than five feet and a half was obtained at St. German's, by which the surface of the waters throughout the whole of the Middle and South Levels was reduced in proportion. Thus the pressure on all the banks along the rivers of the Level was greatly relieved, whilst inundations were prevented, and the sluices provided for the evacuation of the inland waters were enabled effectually to discharge themselves.

By labours as these an immense value has been given to otherwise worthless swamps and wastes. The skill of the engineer has enabled the Fen farmers to labour with ever-increasing profit, and to enjoy the fruits of their industry in comparative health and comfort. No wonder that they love the land which has been won by toil so protracted and so brave. Unpicturesque though the Fens may be to eyes accustomed to the undulating and hill country of the western districts of England, they nevertheless possess a humble beauty of their own, especially to eyes familiar to them from childhood. The long rows of pollards, with an occasional windmill, stretching along



the horizon as in a Dutch landscape—the wide extended flats of dark peaty soil, intersected by dykes and drains, with here and there a green tract covered with sleek cattle—have an air of vastness, and even grandeur, which is sometimes very striking. To this we may add, that the churches of the district, built on sites which were formerly so many oases in the watery desert, loom up in the distance like landmarks, and are often of remarkable beauty of outline.

It has been said of Mr. Rennie that he was the greatest "slayer of dragons" that ever lived,—this title being given in the Fens to persons who, by skill and industry, have perfected works of drainage, and thereby removed the causes of sickness and disease, typified in ancient times as dragons or destroyers.* In this sense, certainly, Mr. Rennie is entitled, perhaps more than any other man, to this remarkable appellation.

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* Thompson's 'History of Boston,' 1856, p. 639.

CHAPTER VI.

MR. RENNIE'S BRIDGES.

THE bridges erected by our engineer are amongst the finest of his works, and sufficient of themselves to stamp him as one of the greatest masters of his profession. We have already given a representation of his first bridge, erected over the Water of Leith, near Edinburgh, the forerunner of a series of similar structures unrivalled for solidity and strength, contrived with an elegance sometimes ornate, but for the most part of severe and massive simplicity.

Unlike some of his contemporaries, Mr. Rennie did not profess a disregard for theory; for he held that true practice could only be based on true theory. Taken in the sense of mere speculative guessing, however ingenious, he would have nothing to do with it; but as matter of inference and demonstration from fixed principles, he held by theory as his sheet-anchor. His teacher, Professor Robison, had not failed to impress upon him its true uses in the pursuit of science and art; and he never found reason to regret the fidelity with which he carried out his instructions in practice.

In the year 1793, Mr. Rennie had the advantage of much close personal intercourse with his old friend the Professor, who paid him a visit at his house in London, for the express purpose of conferring with him upon mechanical subjects. In the letter announcing the object of his visit, Dr. Robison candidly avowed that it was in order "that he might extract as much information from him as possible." The Doctor had undertaken to prepare the articles on Mechanics for the third edition of the 'Encyclopedia Britannica,' and he believed he should be enabled to impart an additional value to his writings by throwing upon them the light of Rennie's strong practical judgment. He proposed to take a lodging in the immediate neighbourhood of Rennie's house, then in Great Surrey Road, and to board with him during the day; but Rennie would not listen to this proposal, and insisted on being the Professor's entertainer during the period of his visit.

One of the points which he particularly desired to discuss with Mr. Rennie was the theory of the equilibrium of arches—a subject at that time very imperfectly understood, but which the young engineer had studied with his usual energy and success. He had clearly proved that the proper proportion and depth of the key-stone to that of the extrados (or exterior curve) should be in proportion to the size and form of the arch and the materials of which it was composed; and he had also established the ratio in which the arch-stones should increase from the key-stone to the piers or abutments.

Up to this time there had been no rules laid down for the guidance of the engineer or architect,—who worked very much in the dark as to principles; and it was often a matter entirely of chance whether a bridge stood or fell when the centres were removed. According to the views of Hutton and Attwood, the weight upon the haunches and abutments, to put the arch in a state of equilibrium so that it should stand, was unlimited; whereas Mr. Rennie established the limit to which the countervailing force or weight on the extrados should be confined. Hence he adopted the practice of introducing a flat inverted arch between the extrados of each two adjoining arches, (at the same time increasing the width of the abutment,) —the radii of the voussoirs or arch-stones being continued completely through them. And in order to diminish the masonry, the lower or foundation course was inclined also,

—thus combining the work more completely together, and enabling it better to resist the lateral thrust.

Dr. Robison had much discussion with Mr. Rennie on these and many other points, and the information he obtained was shortly after worked up into numerous original contributions of great value; amongst which may be mentioned his articles in the 'Encyclopedia' on the Arch, Carpentry, Roof, Waterworks, Resistance of Fluids, and Running of Rivers *—on all of which subjects Mr. Rennie had communicated to him much original information. It may readily be imagined that the evenings devoted by Dr. Robison to conversation and discussion on such topics at Rennie's house were of interest and advantage to both; and when the Doctor returned to his Edinburgh labours, he carried with him the cordial affection and respect of the engineer, who continued to keep up a correspondence with him until the close of his life.

In the early part of his career Mr. Rennie was called upon to furnish designs of many bridges, principally in Scotland, which, however, were not carried out, in most cases because the requisite funds could not be raised to build them. Thus, in 1798, he designed one of eight cast-iron arches to span the river Don at Aberdeen. Four years later he was called upon to furnish further designs, when he supplied three several plans, two of granite bridges; but the structures were of too costly a character, and the people of Aberdeen did not carry them out.

The first important bridge which Mr. Rennie was authorised to execute was that across the Tweed at Kelso, and it afforded a very favourable specimen of his skill as an architect. It was designed in 1799 and opened in

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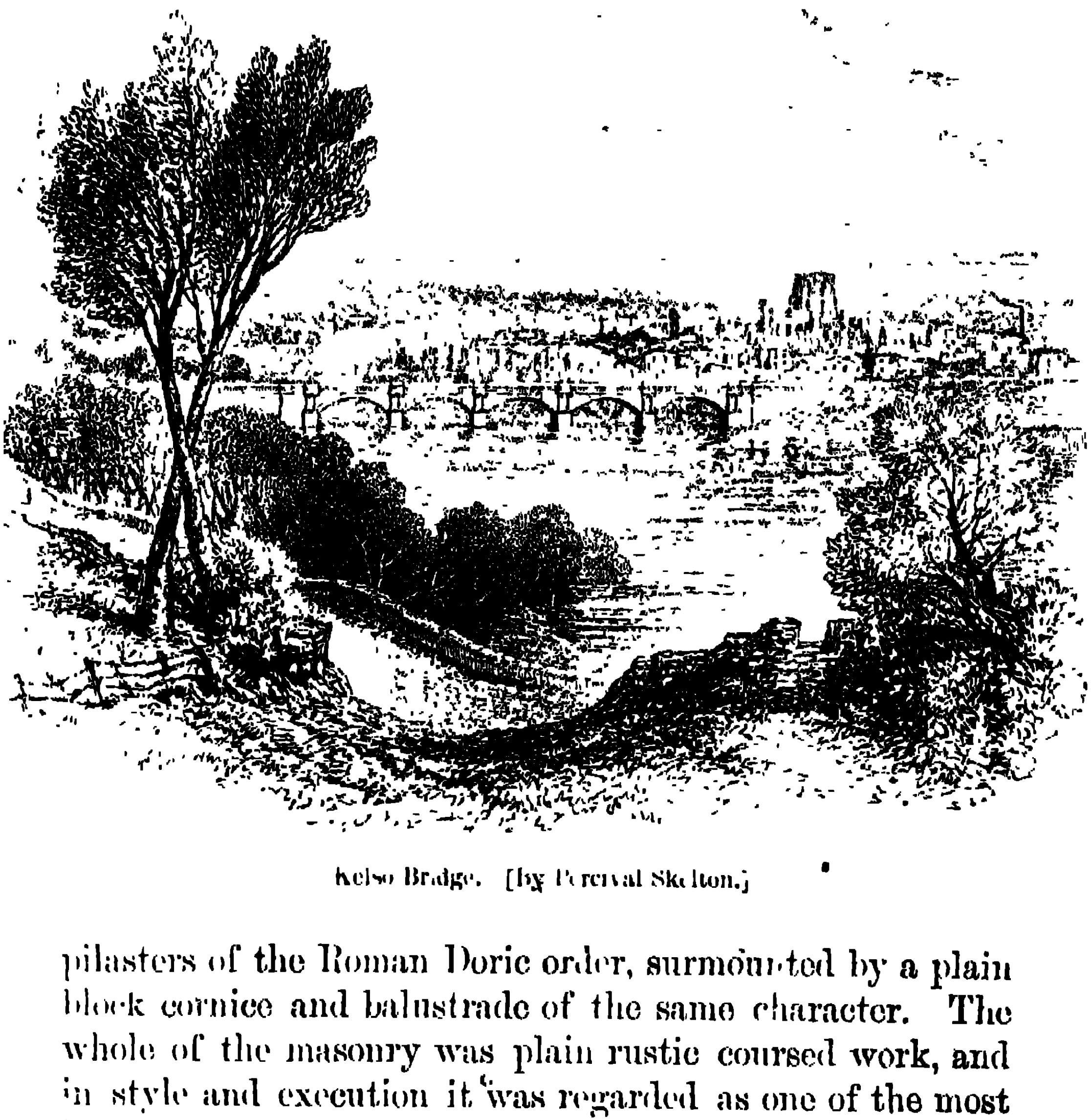
* Dr. Robison was the first contributor to the 'Encyclopedia' who was really a man of science, and whose articles were above the rank of mere compilations. He sought information from all quarters—searched the works of foreign writers, and consulted men of practical eminence, such as Rennie, to whom he could obtain access—and hence an extraordinary value was imparted to his articles.

1803. It consists of five semi-elliptical arches of 72 feet span, each rising 28 feet, and four piers each 12 feet thick, with a level roadway 23 feet 6 inches wide between the parapets, and 29 feet above the ordinary surface of the river. The foundations were securely laid upon the solid rock in the bed of the Tweed, by means of coffer-dams, and beneath the deepest part of the river. The piers and abutments were ornamented with three-quarter columnar pilasters of the Roman Doric order, surmounted by a plain block cornice and balustrade of the same character. The whole of the masonry was plain rustic coursed work, and in style and execution it was regarded as one of the most handsome and effective structures of its kind.



Kelso Bridge. [By Percival Skelton.]

The Kelso Bridge may almost be said to have formed the commencement of a new era of bridge-building in this country. The semi-elliptical arches, the columnar pilasters on the piers, the balustrade, and the level roadway, are the same as in Waterloo Bridge, except as regards size and character; so that Kelso Bridge may be regarded as the model of the greater work. We believe it was one of the first bridges in this country constructed with a *level* roadway.

Musselburgh Bridge. [By E. M. Wimperis, after a Drawing by J. S. Smiles.]

Some of the old-fashioned bridges were excessively steep, and to get across them was like climbing over the roof of a house. There was a heavy pull on one side and a corresponding descent on the other. The old bridge across the Esk at Musselburgh, forming part of the high road between Edinburgh and London, was of this precipitous character. It was superseded by a handsome and substantial bridge, with an almost level roadway, after a design by Rennie. When the engineer was taking the work off the hands of the contractor, one of the magistrates of the town, who was present, asked a countryman who was passing at the time with his cart how he liked the new brig? "Brig!" said the man, "it's nae brig ava! ye neither ken whan ye're on't, nor whan ye're off't!"

Mr. Rennie's boldness in design grew with experience, and when consulted as to a bridge near Paxton, over the Whitadder (a rapid stream in Berwickshire), he proposed, in lieu of the old structure, which had been carried away by a flood, a new one of a single arch of 150 feet span; but unhappily the road trustees could not find the requisite means for carrying it into effect.

Another abortive but grand design was proposed by him in 1801. He had been requested by the Secretary of State for Ireland to examine the road through North Wales to Holyhead, with the object of improving the communication with Ireland, which was then in a wretched state. The connection of the opposite shores of the Menai Strait by means of a bridge was considered an indispensable part of any improvement of that route; and Mr. Rennie proposed to accomplish this object by a single great arch of cast iron 450 feet in span,—the height of its soffit or crown to be 150 feet above high water at spring tides.* A similar bridge of 350 feet span, having its crown 100 feet above the same level, was also proposed by him for the crossing of Conway Ferry.

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* The great arch of 450 feet was to be supported on two stone piers, each 75 feet thick, the springing to be 100 feet above high water There were to be arches of stone on the Caernarvon side to the distance of about 156 yards, and on the Anglesea side to the distance of about 284 yards; making the total length of the bridge, exclusive of the wing walls, about 640 yards. The estimated cost of the whole work and approaches was 268,500*l.* The point at which the bridge was recommended to be thrown across was, either opposite Inys-y-Moch island, on which one of the main piers would rest, or at the Swilly rocks, about 800 yards to the eastward; but, on the whole, he preferred the latter site. He also sent in a subsequent design, showing an iron arch on each side of the main one of 350 feet span, in lieu of masonry, with other

These bridges were to be manufactured after a plan invented by Mr. Rennie in 1791, and communicated by him to Dr. Hutton in 1794; and he was strongly satisfied of its superiority to all others that had been proposed. The designs were alike bold and skilful, and it is to be regretted that they were not carried out; for their solidity would not only have proved sufficient for the purposes of a roadway, but probably also of a locomotive railway. In that case, however, we should have been deprived of the after-display of engineering ability in bridging the straits at Menai and the ferry at Conway. Rennie's plans were, however, thought far too daring, and the expense of executing them far too great. The whole subject was therefore allowed to sleep for many years, until eventually Telford spanned both these straits with suspension road bridges, and Robert Stephenson afterwards with tubular railway bridges, at a total cost of about a million sterling.

The first bridge constructed by Mr. Rennie in England, and the earliest of his cast-iron bridges, was that erected by him over the Witham, in the town of Boston, Lincolnshire, in 1803. It consists of a single arch of iron ribs, forming the segment of a circle, the chord of which is 80 feet. It is simple yet elegant in design; its flatness and width contributing to render it most convenient for the purpose for which it was intended—that of accommo-

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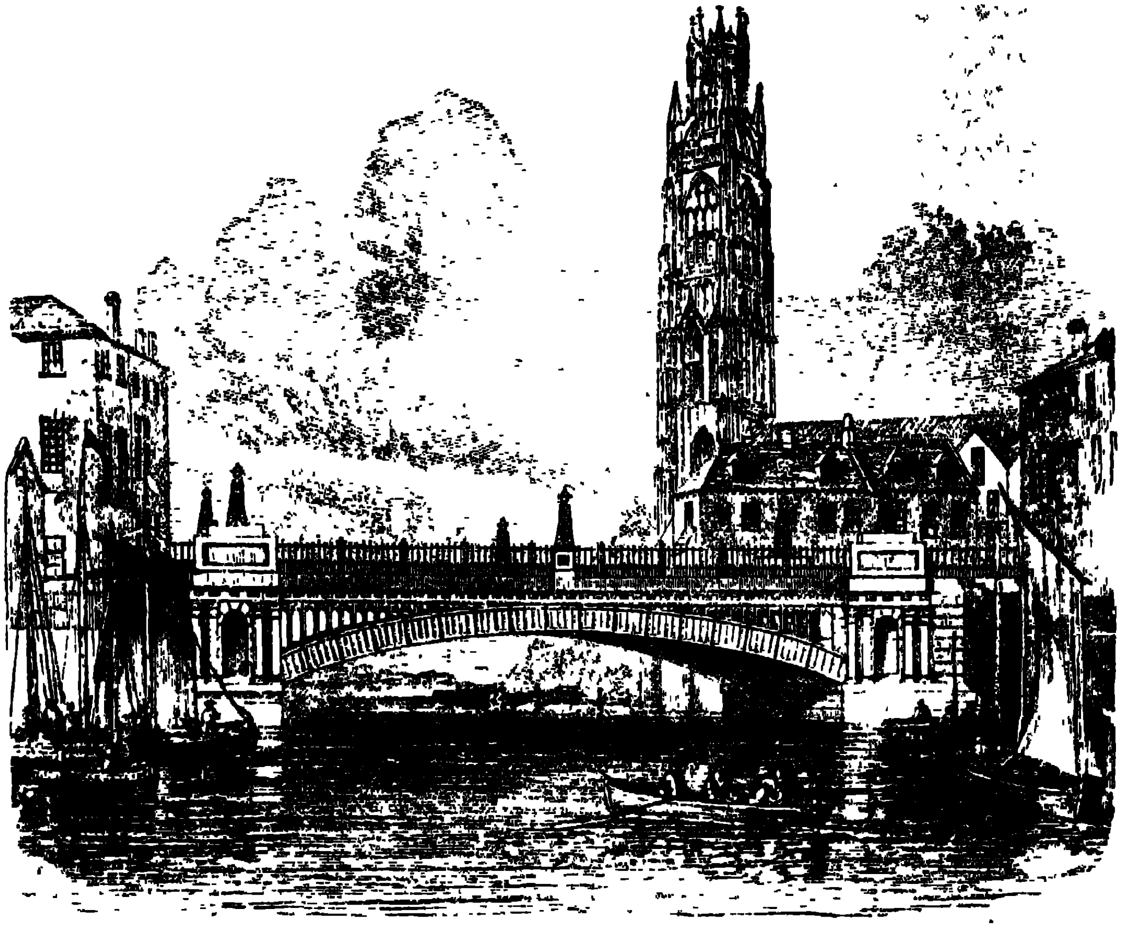
modifications, by which the dimensions of the main piers were reduced, and the estimate somewhat lessened. Other plans were prepared and submitted, embodying somewhat similar views, the prominent idea in all of them being the spanning of the strait by a great cast-iron arch, the crown of which was to be 150 feet above the sea at high water. The plans and evidence on the subject are to be found set forth in the 'Reports from Committees of the House of Commons on Holyhead Roads' (1810-22), ordered to be printed 25th July, 1822.

dating the street-traffic of one of the most prosperous and busy towns in the Fens.



Boston Bridge. [By Percival Skelton.]

Mr. Rennie's reputation as an engineer having become well established by works of this class, he was, during the remainder of his professional career, extensively consulted on this branch of construction;* and many solid memorials of his skill in bridge-work are to be found in different parts of the kingdom. But the finest of the buildings of this character which were erected by him are unquestionably those which adorn the metropolis itself.

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* Among his minor works may be mentioned the bridge over the stream which issues out of Virginia Water and crosses the Great Western Road (erected in 1805); Darlaston Bridge across the Trent, in Staffordshire (1805); the timber and iron bridge over the estuary of the Welland at Fossdyke Wash, about nine miles below Spalding (1810); the granite bridge of three arches at New Galloway, on the line of the Dumfries and Portpatrick Road (1811); a bridge of five arches across the Cree at Newton Stewart (1812); the cast-iron bridge over the Goomtee at Lucknow, erected after his designs in 1814, and frequently referred to in the mili-

The project of erecting a new bridge to connect the Strand, near Somerset House, with the Surrey side of the Thames at Lambeth, was started by a Bridge Company in 1809—a year distinguished for the prevalence of one of those joint-stock fevers which periodically seize the moneyed classes of this country. The first plan considered was the production of Mr. George Dodds, a well-known engineer of the time. The managing committee were not satisfied with the design, and referred it to Mr. Rennie and Mr. Jessop for their opinion. It was found to be for the most part a copy of M. Peyronnet's celebrated bridge of

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tary operations for the relief of that city a few years ago; Wellington Bridge, over the Aire, at Leeds (1817); Isleworth Bridge (1819); a bridge of three elliptical arches of 75 feet span each, at Bridge of Earn, Perthshire (1819); Cramond Bridge, of eight semicircular arches of 50 feet span, with the roadway 42 feet above the river (1819); and Ken Bridge, New Galloway, of five stone arches, the centre 90 feet span (1820). An adventure of some peril attended Mr. Rennie's erection of the bridge at Newton Stewart. He happened to visit the works on one occasion during a heavy flood, which swept down the valley with great fury; and the passage of the ferry was thus completely interrupted. Mr. Rennie and his son (the present Sir John) were consequently unable to cross over to Newton Stewart. About 11 P.M. the violence of the storm had somewhat abated, and the moon came out, though obscured by the clouds which drifted across her face. Mr. Rennie went out at that late hour to look at the bridge works, and even to try whether he might not reach the other side by crossing the timber platform by means of which the works were being carried on. There was a gangway of only two planks from pier to pier on the eastern side, and this he safely crossed. The torrent was still raging furiously beneath, shaking the frail timbers of the scaffolding. As Mr. Rennie was about to place his foot on the plank which led to the third pier, his son observed the framework tremble, and pulled his father back, just in time to see the whole swept into the stream with a tremendous crash. Fortunately the planking still stood across which they had passed, and they succeeded in retracing their steps in safety. The bridge was finished and opened during the summer of 1814.

Neuilly, with modifications rendered necessary by the difference of situation and the greater width of the river to be spanned. It showed a bridge of nine arches of 130 span: each being a compound curve, the interior an ellipse and the face or exterior a segment of a circle, as in the bridge at Neuilly.* The reporting engineers pointed out various objections to the design, as well as to the plan proposed for founding the piers. The result was, that no further steps were taken to carry out Mr. Dodd's plan; but when the Act authorising the construction of the bridge had been obtained, the committee again applied to Mr. Rennie; and on this occasion they requested him to furnish them with the design for a suitable structure.*

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* In their report on this design, Mr. Rennie and his colleague observed:—"We should not have thought it necessary to quote the production of a foreign country for the sake of showing the practicability of constructing arches of 130 feet span, had we not been led to it by the exact similarity of the designs, and by the principle which is therein adopted of the compound curve; because our own country affords examples of greater boldness in the construction of arches than that of Neuilly. There is a bridge over the river Taff, in the county of Glamorgan, of upwards of 135 feet span, with a rise not exceeding 32 feet, and what is more remarkable is, that the depth of the arch-stones is only 30 inches; so that in fact that bridge far exceeds in boldness of design that of Neuilly." [See the Memoir of William Edwards at p. 73.] After some observations as to the importance and necessity of making a bridge in such a situation at the bend of the river, with as large arches as possible, to accommodate the navigation and present as little obstruction as possible to the rise and fall of the water, they proceeded:—"We confess we do not wholly approve of M. Peyronnet's construction as adapted for the intended situation. It is complicated in its form, and, we think, wanting in effect. The equilibrium of the arches has not been sufficiently attended to; for when the centres of the bridge at Neuilly were struck, the top of the arches sank to a degree far beyond anything that has come to our knowledge, whilst the haunches retired or rose up, so that the bridge as it now stands is very different in form from what it was originally designed. No such change of shape took place in the bridge over the Taff (Pont-y-Prydd); the sinking after the centres were struck did not amount to one-half of that at Neuilly, although the one was designed and built under the direction of the first engineer of France, without regard to expense, whilst the other was designed and built by a country mason with parsimonious economy. Our opinion therefore is, that the arches of the bridge over the Thames should either be plain ellipses, without the slanting off in the haunches so as to deceive the eye by an apparent flatness which does not in reality exist, or they should be of a flat segment of a circle formed in such a manner as to give the requisite room for the passage of the current and barges under it."

The first step which he took was to prepare an entirely fresh chart of the river and the adjacent shores, after a careful and accurate survey made by Mr. Francis Giles. In preparing his plan, he kept in view the architectural elegance of the structure as well as its utility; and while he designed it so as to enhance the beauty of the fine river front of Somerset House, by contriving that the face of the northern abutment should be on a line with its noble terrace, he laid out the roadway so that it should be as nearly upon a level with the great thoroughfare of the Strand as possible—the rise from that street to the summit on the bridge being only 1 in 250, or about two feet in all. Two designs were prepared--one of seven equal arches, the other of nine; and the latter being finally approved by the committee as the less costly, it was ordered to be carried into effect.

The structure, as executed, is an elegant and substantial bridge of nine arches of 120 feet span, with piers 20 feet thick; the arches being plain semi-ellipses, with their soffits or crowns 30 feet above high-water of ordinary spring tides. Over the points of each pier are placed two three-quarter Doric column pilasters, after the design of the temple of Segesta in Sicily. These pilasters are 5 feet 8½ inches diameter at the base, and 4 feet 4 inches at the under side of the capital, forming recesses in the roadway 17 feet wide and 5 feet deep. The depth of the arch-stones at the crown is 4 feet 6 inches, and they increase regularly to 10 feet at the haunches. Between each pair of arches, at the level of 19 feet above the springing, there is an inverted arch, the stones of which are 4 feet six inches deep at the crown, and decrease regularly on each side as they unite and abut against the extrados or backs of the voussoirs of the main haunches. The abutments are 40 feet in thickness at the base, and decrease to 30 feet at the springing. The cope of the arches and piers is surmounted by a Grecian Doric block-cornice and entablature, upon which is placed a balustrade parapet 5 feet high. The total width of the bridge from outside to outside of the parapets is 45 feet. The footpaths on each side are 7 feet wide, and the roadway for carriages 28 feet. There were originally four sets of landing stairs—two to each abutment; and the arrangement of this part of the work has been much admired, on account of its convenience, as well as because of its architectural elegance.

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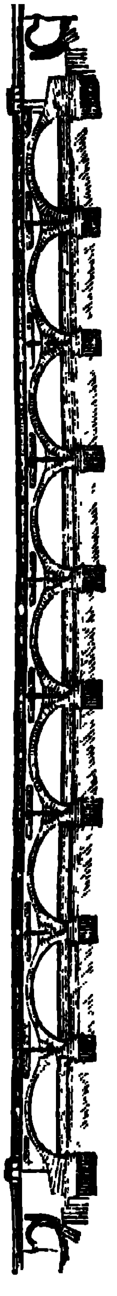
* In June, 1810, we find him accepting the direction of the new bridge at 1000*l.* a-year for himself and assistants, or 7*l.* 7*s.* a-day and expenses; but on no account were any of his people to have to do with the payment or receipt of moneys.



Section of Waterloo Bridge.

In the construction of this bridge there are four features of distinctive importance to be noted:—1st. The employment of coffer-dams in founding piers in a great tidal river—an altogether new use of that engineering expedient, though now become customary. 2nd. The ingenious method employed for constructing, floating, and fixing the centres; since followed by other engineers in works of like magnitude. 3rd. The introduction and working of granite stone to an extent before unknown, and in much larger and more substantial pieces of masonry than had previously been practised. 4th. The adoption of elliptical stone arches of an unusual width, though afterwards greatly surpassed by the same engineer in his New London Bridge.

Mr. Rennie invariably took the greatest pains in securing the most solid foundations possible for all his structures, and especially of his river works, laying them far below the scour of the river, at a depth beyond all probable reach of injury from that cause. The practice adopted in founding the piers of the early bridges across the Thames was to dredge the bottom to a level surface, and build the foundations on the bed of the river, protecting them outside by rubble, by starlings, or by sheet-piling. Mr. Dodds had proposed to follow the method employed by Labelye at Westminster Bridge, of founding the piers by means of caissons; but Mr. Rennie insisted on the total insufficiency of this plan, and that the most effectual method was by means of coffer-dams. This would, no doubt, be more costly in the first instance, but vastly more secure; and he foresaw that the inevitable removal of the piers of Old London Bridge, by increasing the current of the river, would severely test the foundations of all the bridges higher up the stream—which proved to be the case. Having already extensively employed coffer-dams in getting in the foundations of the London and East India Dock walls, he had no doubt as to their success in this case; and they were adopted accordingly.*

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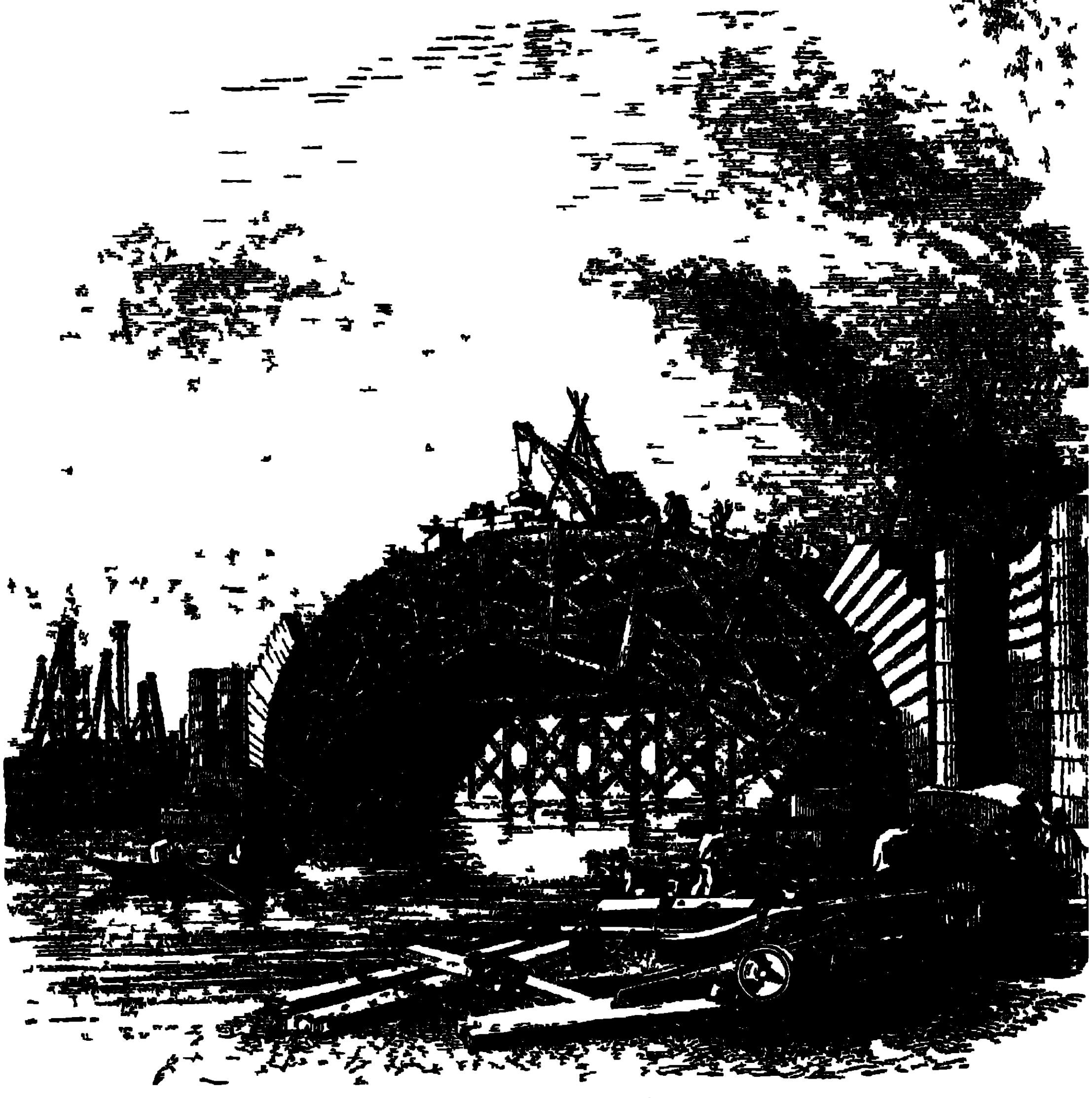
* The coffer-dams in which the foundations of the abutments were built, were formed by driving two rows of piles 13 by 6½ inches each, with a counter or abutting pile at every 12 feet 12 by 12, driven in the form of an ellipsis, and strongly cemented together, at low-water and high-water levels, by double horizontal walings or bracks, having a space of about 8 inches clear between them for the intermediate or half piles. The whole were driven close together from 15 to 20 feet deep into the ground, well caulked, so as to be water-tight, and all connected firmly together by strong wrought iron bars and bolts, besides shores and intermediate braces The spaces between the two rows of piles were then rammed close with well-tempered clay, so that they formed as it were, a solid vat or tub impermeable to water; and within these, when pumped clear of water, the excavation was made to the proper depth, and in the space so dug out the building operations proceeded. The coffer-

Mr. Rennie also introduced a practice of some novelty and importance in the centering upon which the arches of



Centering of Arch, Waterloo Bridge. [After E. Blore.]

the bridge were built. He adopted the braced principle. The centres spanning the whole width of the arch were

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dams for the piers were formed in a similar manner, with modifications according to circumstances. By this means the bed of the river, where the piers were to be erected, was exposed and dug out to the proper depth, and the foundations were commenced from a level nine feet at least below low-water mark. The foundations there rested upon timber piles from 20 to 22 feet long, driven into the composed of eight ribs each, formed in one piece, resting upon the same number of solid wedges, supported by inclined tressels placed upon longitudinal bearers, firmly fixed to the offset of the piers and abutments. At the intersecting point of the bearers or braces in each rib there was a cast-iron box, with two holes or openings in it, so that the butt-ends rested firmly against the metal; and to prevent them from acting like so many wedges to tear the rib to pieces when the vertical weight of the arch began to act upon them, pieces of hard wood were driven firmly into the holes above described, to check the effect of the bearers or struts of the ribs; and this arrangement proved completely successful. The eight ribs were firmly connected together by braces and ties, so as to form one compact frame, and the curve or form of the arch was accurately adjusted by means of transverse timbers, 12 inches wide and 6 inches thick, laid across the whole of the ribs, set out to the exact form of the curve by ordinates from the main or longitudinal axis of the ellipsis; and in proportion as the voussoirs or arch-stones were carried up from the adjoining piers, the weight which had been laid upon the top of the centre to keep it in equilibrium according to the form of the arch during construction, was gradually removed as it advanced towards completion. When the arch was about two-thirds completed, a small portion of it was closed with the centre, and the remaining part of each side was brought forward regularly by offsets to the crown until the whole was finished. Each key-stone was accurately fitted to its respective place, and the last portion of each, for the space of about eighteen inches, was driven

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solid bed of the river. Upon the heads of these piles half-timber planking was spiked, and on this the solid masonry was built—every stone being fitted, mortared, and laid with studious accuracy and precision. The whole work was done with such solidity that, after the lapse of fifty years, the foundations have not yielded by a straw's breadth at any point.

home by a heavy wooden ram or pile-engine, so as almost to raise the crown of the arch from the centre.

About ten days after the main arches had been completed, and the inverts and spandrel walls between them carried up to the proper height, the arches were gently slackened, to the extent of about two inches, so as to bring each to its bearing to a certain extent. This was effected by driving back the wedges upon which the ribs of the centres rested, by means of heavy wooden rams attached to them, so that they could swing backwards and forwards with great facility when any external force was applied to them; and this was done by ropes worked by hand-labour. After the first striking or slackening, the arches were allowed to stand for ten days, when the wedges were driven back six inches farther. After ten days more the wedges were driven back sufficiently to render the arch altogether clear of the centering. By this means the mortar was firmly imbedded into all the joints, and the arch came gradually to its ultimate bearing without any undue crushing. In order to ascertain whether any change of form took place, three straight lines were drawn in black chalk on the extreme face of the arch previous to commencing the operation of striking the centre—one horizontally in the centre of the voussoirs forming the crown, and two from the haunches of the arch, each intersecting the first line at about 25 feet on each side of the keystone; so that if there had been any derangement of the curve or irregular sinking, it would at once have been clearly apparent. After the centres had been removed, it was found that the sinking of the arches varied from 2½ to 3¼ inches, which was as nearly as possible the allowance made by the engineer in designing the work; the whole plan being worked out with admirable precision and accuracy.

The method of fixing and removing the centres was entirely new; being precisely the same as was afterwards followed by Mr. Robert Stephenson in fixing the wrought-iron ribs of the Conway and Britannia bridges—that is, by constructing them complete upon a platform adjacent to the river, and floating them between the piers on barges expressly contrived for the purpose. They were then raised into their proper places by four strong screws, 8 inches in diameter and 4 feet long, fixed in a strong cast-iron box firmly bedded in the solid floor of the barge. The apparatus worked so well and smoothly, that the whole centre, consisting of eight ribs, each weighing about fifty tons, was usually placed within the week.

The means employed by Mr. Rennie for forming his road upon the bridge, were identical with those adopted by Mr. Macadam at Bristol some six years later. But the arrangement constituted so small a part of our engineer's contrivances, that, as in many other cases, he made no merit of it. When the clay-puddle placed along the intended roadway was sufficiently hard, he spread a stratum of fine screened gravel or hoggins, which was carefully levelled and pressed down upon the clay. This was then covered over with a layer of equally broken flints, about the size of an egg; after which the whole was rolled close together, and in a short time formed an admirable "macadamized" road. Mr. Rennie had practised the same method of making roads over his bridges long before 1809; and he continued to adopt it in all his subsequent structures.

The whole of the stone required for the bridge (excepting the balustrades, which were brought ready worked from Aberdeen) was hewn in some fields adjacent to the erection on the Surrey side. It was transported to the work upon trucks drawn along railways, in the first instance over temporary bridges of wood; and it is a singular circumstance that nearly the whole of the material was drawn by one horse, called "Old Jack"—a most sensible animal, and a great favourite. His driver was, generally speaking, a steady and trustworthy man, though rather too fond of his dram before breakfast. As the railway along which the stone was drawn, passed in front of the public-house door, the horse and truck were usually pulled up while Tom entered for his "morning." On one occasion the driver stayed so long that "Old Jack," becoming im-

Waterloo Bridge [By Percival Skelton, after his original Drawing]

patient, poked his head into the open door, and taking his master's coat collar between his teeth, though in a gentle sort of manner, pulled him out from the midst of his companions, and thus forced him to resume the day's work.

The bridge was opened with great ceremony by His Royal Highness the Prince Regent, attended by the Duke of Wellington and many other distinguished personages, on the 18th of June 1817. It was originally named the Strand Bridge; but after that date the name was altered to that of "Waterloo," in honour of the Duke. At the opening, the Prince Regent offered to confer the honour of knighthood on the engineer, who respectfully declined it. Writing to his friend Whidbey, he said, "I had a hard business to escape knighthood at the opening." He was contented with the simple, unadorned name of John Rennie, engineer and architect of the magnificent structure which he had so successfully brought to completion.

Waterloo Bridge is indeed a noble work, and probably has not its equal for size, beauty, and solidity. Dupin characterised it as a colossal monument, worthy of Sesostris or the Cæsars. Canova, during his visit to England, was particularly struck by the fact, that the trumpery Chinese bridge, in St. James's Park, should be the production of the Government, whilst Waterloo Bridge was the enterprise of a private company. Like all Rennie's works, it was built for posterity. That it should not have settled more than a few inches—not five in any part—after the centres were struck, is an illustration of solidity and strength probably without a parallel. We believe that not a crack is visible in the entire work.

The necessity for further bridges across the Thames increased with the growth of population on both sides of the river. In the year 1813, a Company was formed to provide a bridge at some point intermediate between Blackfriars and London Bridge, of which Mr. Rennie was appointed the engineer. The scheme was at first strongly opposed by the Corporation, on the ground of the narrowness of the river at the point at which it was proposed to erect the new structure; but the public demands being urgent, the necessary Act was at length allowed to pass, but the Corporation insisted on the provision of a very large waterway, so that the least possible obstruction should be offered to the navigation. Mr. Rennie prepared a design to meet the necessities of the case, and in order to secure the largest waterway, he projected his well-known Southwark Bridge—extending from Queen Street, Cannon Street, to Bridge Street, Southwark. It consists of three cast-iron arches, with two stone piers and abutments. The arches are flat segments of circles, the centre one being not less than 240 feet span (or 4 feet larger than Sunderland Bridge, the largest cast-iron arch that had until then been erected), rising 24 feet, and springing 6 feet above high water of spring tides. The two side arches are of 210 feet span, each rising 18 feet 10 inches, and springing from the same level. The two piers were 24 feet wide each at the springing, and 30 feet at the base.

The works commenced with the coffer-dam of the south pier on the Southwark side, and the first stone was laid by Admiral Lord Keith about the beginning of 1815. All the centering for the three arches was fixed by the autumn of 1817, and the main ribs were set by the end of April 1818. The centres were struck by the end of the month of June following, and completely removed by the middle of October; and the bridge was opened for traffic in March 1819.

In the course of this work great precautions were used in securing the foundations of the piers. The river was here at its narrowest and deepest point, the bed being 14 feet below low water of ordinary spring tides. The coffer-dams were, therefore, necessarily of great depth and strength to resist the pressure of the strong body of water, as well as the concussion of the barges passing up and down the river, which frequently drove against them. Hence the dams were constructed in the form most capable of resisting external pressure, and yet suitable to the dimensions of the foundations. The masonry and iron work of the bridge were erected with great care and completeness. The blocks of stone in the piers were accurately fitted to their places by moulds, and driven down by a heavy wooden ram.

Southwark Bridge. [By Percival Skelton, after his original Drawing.]

The least possible quantity of finely-tempered mortar was used, so that every part should have a perfectly true permanent bearing. Great care was also taken in the selection of the blocks. The exterior of the piers was constructed of hard silicious stone brought from Craigleith Quarry, near Edinburgh, and Dundee; the interior, from the bottom of the foundations to the springing of the arches, of hard Yorkshire grit; while that part of the piers and abutments from which the arches spring consisted of the hardest and closest blocks of Cornish and Aberdeen granite: in fine, it may be affirmed that a more solid piece of masonry does not exist than Southwark Bridge.

The iron work consists of eight arched ribs, the main strength of the arches being embodied in their lower parts, which are solid. The lower or main arch is divided into thirteen pieces, with a rib 5½ inches thick at the top and bottom, and 2½ inches in the centre. The joints radiate outwards from the lower edge, and form so many cast-iron instead of stone voussoirs, from 6 to 8 feet deep and 13 feet long. At the junction of each of these main rib pieces there are transverse plates of the same depth, having flanges cast upon them on both sides in a wedge form, so that the ends of the main rib piers fit into them on one side, whilst on the other there is a cast-iron wedge, driven in between the rib and flange piece, and enabling the whole to be accurately adjusted and connected together. In addition to this, each rib piece had a flange, cast at each end with a certain number of holes three-quarters of an inch in diameter, into which wrought-iron screw bolts were introduced to connect the whole firmly together in the direction of the arch. These rib pieces were also of great importance during construction, the chief dependence being placed upon their lateral thrust in holding the arches together.

At each pier and abutment there was a similar cast-iron bed or abutting plate, let accurately 1½ inch into the stone; but between the end of each main rib which sprang from this plate there was a groove cut out of the solid stone behind the springing plates and main iron ribs of the arches, 18 inches wide, 3 inches thick at the top, and 2 inches at bottom. The groove was accurately dressed and polished. Three cast-iron wedges, 9 feet long, 6 inches wide, and 3½ inches thick at top and 2 inches at bottom, were then made and most accurately chipped and filed, so as to fit exactly the groove above mentioned to within 12 inches of its bottom. When the whole of these wedges at both ends of the arch had been put into their places, they were carefully driven home to the bottom of the grooves at the same time by heavy wooden rams, by which means the ribs of the arches were relieved from the centres and took their own bearing. In other words, the arches were keyed from the abutments only, instead of from the centre, as is usual in bridges of stone.

This was an extremely delicate and nice process, as it required that the variations of the thermometer should be carefully observed, in order that each operation should be carried on at as nearly as possible the same degree of temperature, otherwise the form of the arch would have been distorted, the vertical and lateral pressure of the different parts would have been affected, and an undue strain thrown upon the abutments as well as the different parts of the arch. But so nicely was the whole operation arranged and adjusted, that nothing of the kind occurred the parts remained in perfect equilibrium; not a bolt was broken, and not the smallest derangement was found in the structure after the process had been completed.

The spandrel pieces attached to the top of the main ribs were cast in the form of open diamonds or lozenges, connected together in the transverse direction by two tiers of solid crosses laid nearly horizontally—all closely wedged and firmly bolted together. In addition to the transverse connecting plates cast in open squares, there were also diagonal braces of cast iron, commencing at the extremity of the outer rib of each arch and intersecting each other so as to form a diamond-shaped space in the centre

These were also secured at their ends by wedges and bolts, like the main rib pieces.

After the main ribs of the arches were relieved from the centres, and had taken their bearing, before the centres were removed from beneath them, experiments were made how far they might be affected by expansion and contraction, in proportion to the different degrees of temperature to which the bridge might be exposed; and for this purpose different gauges were made of brass, iron, and wood. These gauges were firmly attached to the middle or crown of the wooden centres, and divided into sixteenths of an inch, and at each a Fahrenheit thermometer was placed; so that the ends of the arch being fixed, the variation in the temperature would be indicated by the rise and fall in the centre. The observations were made daily—in the morning, at midday, and at sunset—for several months during summer and winter, when it was ascertained that the arches rose and fell about one-tenth of an inch for every 10 degrees of temperature, more or less.

The whole iron work is covered with solid plates, having flanges cast on their upper side. These plates are laid in the transverse direction and on the top of the spandrel walls, so that they form a solid and compact cast-iron floor to support the roadway. The cornice, which is cast hollow, is of the plain Roman-Doric order, and is secured to the roadway-plates by strong stays and bolts at proper intervals. The parapet consists of a plinth, also cast hollow, with a groove at the top to receive the railing, which is cast in the form of open diamonds corresponding with the spandrels. The roadway is 42 feet wide from outside to outside, and formed in the same manner as that over Waterloo Bridge, which has been already described.

The total quantity of cast iron in the bridge is 3620 tons, and of wrought iron 112 tons. It has been said that an unnecessarily large quantity of material has been employed; and no doubt a lighter structure would have stood. But looking at the imperfections of workmanship and possible flaws in the castings, Mr. Rennie was probably justified in making the strengths such as he did, in order to ensure the greatest possible solidity and durability—qualities which eminently characterize his works, and perhaps most of all, his majestic metropolitan bridges. Although the Southwark Bridge was built before the Railway era, which has given such an impetus to the construction of iron bridges, it still stands pre-eminent in its class, and is a model of what a bridge should be. Its design was as bold as its execution was masterly. Mr. Robert Stephenson has well said of it that, "as an example of arch construction, it stands confessedly unrivalled as regards its colossal proportions, its architectural effect, and the general simplicity and massive character of its details."*

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* Article on Iron Bridges in 'Encyclopedia Britannica.

Waterloo Bridge. [By R. P. Leitch.]

CHAPTER VII.

THE BELL ROCK LIGHTHOUSE.

ABOUT eleven miles east of the mainland of Scotland, near the entrances to the Friths of Forth and Tay, lies an extensive ledge of rocks, which for a long time was the terror of the seamen navigating that coast. It is nearly two miles in length, being the crest of a mountain rising from the sea bottom, only a small part of which is visible at high water.

This sunken reef was a source of such peril, that, as early as the fourteenth century, the Abbot of Arbroath caused a bell to be placed upon the principal rock, the swinging of which by the motion of the waves warned seamen of its dangers; and from this circumstance it came to be called the Bell Rock. It is affirmed that a notorious pirate, in order to plague the Abbot, cut the bell from the rock, but was himself afterwards wrecked on the very spot; and on this tradition Southey founded his beautiful ballad of 'Ralph the Rover.'*

Nothing was done to replace the bell, or to set a beacon upon the reef; and it remained in its dangerous state—

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* The following is the tradition as given by an old writer:—"By the east of the Isle of May, twelve miles from all land in the German Sea, lyes a great hidden rock called Inchcape, very dangerous to the navigators, because it is overflowed every tide. It is reported that, in old times, there was upon the said rock a bell, fixed upon a tree or timber, which rang continually, being moved by the sea, giving notice to the saylors of the danger. This bell or clocke was put there by the Abbot of Aberbrothock, and, being taken down by a sea-pirate, a yeare thereafter he perished upon the same rock, with ship and goodes, by the righteous judgment of God" (Stoddart's 'Remarks on Scotland.')

the Eddystone of the northern seas—until the beginning of the present century, when the increasing commerce of Scotland, and the large number of vessels wrecked there, had the effect of directing public attention to the subject. As in the case of the Eddystone reef, the sailors' fear of it was such, that in order to avoid its dangers, they hugged the land so close as very frequently to run ashore.

Captain Basil Hall relates that when a boy, he was constantly hearing of vessels getting wrecked through fear of the terrible Bell Rock, which lay about ten leagues due north of the house at Dunglass in which he was born. It is situated on the borders of East Lothian, not far from the bold promontory on which Fast Castle stands, overlooking the German Ocean. He states that "ships bound for the Forth, in their constant terror of the dangerous reef, were not content with giving it ten or even twenty miles of elbow-room, but must needs edge off a little more to the south, so as to hug the shore, in such a way that, when the wind chopped round to the northward, as it often did, these over-cautious navigators were apt to get embayed in a deep bight to the westward of Fast Castle. If the breeze freshened before they could work out, they paid dearly for their apprehensions of the Bell Rock, by driving upon ledges fully as sharp, and far more extensive and inevitable. Thus," he says, "at that time, from three to four, and sometimes half-a-dozen, vessels used to be wrecked every winter, within a mile or two of our very door."*

A Board of Commissioners had been appointed, under the powers of an Act passed in 1786, for the purpose of erecting lighthouses at the most dangerous parts of the coast of Scotland; and by the end of the century several had been built,—one on the Isle of May at the entrance of the Frith of Forth, another on the Cumbraes at the mouth of the Frith of Clyde, and others on rocky promontories on the eastern and western coasts, including the Orkneys. The lights exhibited were of a rude kind, and consisted of coal fires in chauffers. All that was needed being a bright light, they probably answered their purpose, though in a clumsy way. The most dangerous reef of all, however, was still left without any protection; and doubtless the delay in providing a light upon the Bell Rock arose from the great difficulty and expense of erecting a suitable structure on such a site.

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* 'Fragments of Voyages and Travels,' i. 15-16. Edinburgh, 1831.

In the winter of 1799, a tempest memorable for its violence and fatal effects, ravaged the coasts, and drove from their anchors all the ships lying in Yarmouth Roads. The greater number were wrecked on the northern coast; and it was believed that many of them might have been saved, had a light been fixed on the Bell Rock to point out the entrances to the Friths of Forth and Tay. Among the other lamentable shipwrecks which took place on the Inchcape about the same time, was that of the 'York,' a seventy-four-gun ship, which went down with all her crew. The reef was also a constant source of danger to the shipping of Dundee, then rising in importance, as it lay right in the main track of vessels making for the mouth of the Tay from the German Ocean.

Many were the plans suggested for a lighthouse on the Bell Rock. In 1799 Captain Brodie submitted to the Commissioners of Northern Lights his design of a cast-iron tower to be supported on four pillars; but it was not adopted. In the mean time temporary beacons of timber were employed; but these rarely stood the storms of a single winter; and three successive structures of this kind were completely swept away. Mr. Robert Stevenson and Mr. Downie also proposed plans for the consideration of the Board between 1800 and 1804; but neither of them was adopted.

Considerable diversity of opinion continuing to exist, the Commissioners determined to employ Mr. Rennie to examine the site and report as to the best course to be pursued. He accordingly proceeded to Scotland, and visited the Inchcape Rock on the 17th of August, 1805, in company with Mr. Hamilton, one of the Commissioners, and Mr. Stevenson, their surveyor.

After mature deliberation, Mr. Rennie sent in his report on the 30th of December following. He recommended the erection of a substantial lighthouse of stone, similar to that on the Eddystone, as being, in his opinion, the only structure calculated to meet the necessities of the case.* He regarded a wooden building as objectionable, because of the perishable nature of the material, and its liability to be destroyed by fire. Although it would be possible to erect a lighthouse of cast iron, its cost at that time would have been equal to one of stone, with which, in point of durability, it was not to be compared. "I have therefore," he concluded, "no hesitation in giving a decided opinion in favour of a stone lighthouse." With such examples as the Tour de Cordouan near the entrance of the Garonne, and the Eddystone off the coast of Cornwall, he held that there could be no doubt as to the superiority of this plan to any other that could be proposed. Although the Inchcape was not so long uncovered by the tide as the Eddystone rock, and there might be greater delay in getting in the first four or five courses of the foundation, this was only a question of time; and he had no doubt that this difficulty would be overcome, and the whole structure completed in the space of about four years.

In his report he further said: "Mr. Stevenson, to whose merit I am happy to bear testimony, has been indefatigable in obtaining information respecting this rock, and he has made a model of a stone lighthouse nearly resembling that of the Eddystone, in which he has proposed various ingenious methods of constructing the work by way of facilitating the operations. I own, however, after fully considering them, and comparing them with the construction of Mr. Smeaton—I mean in the process of building—and also reflecting that there are undoubted proofs of the stability of the Eddystone, that I am inclined to give the latter the preference; its general construction, in my opinion, rendering it as strong as can well be conceived."

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* Baron Dupin in his 'Commercial Power of Great Britain,' says:—"Several engineers submitted plans; but, by the advice of Mr. Rennie, the model and dimensions of the Eddystoen Lighthouse were adopted with the improvements in lighting, which the recent progress in optics allowed him to make." (ii. 159.)

Taking, however, into account, that the foundation of the proposed building lay so much lower in the sea, Mr. Rennie suggested that the column should be somewhat higher, so that the eave of the cupola should be about 100 feet above the surface of the rock, the Eddystone being only 84 feet 6 inches,—though this alteration would involve a somewhat greater diameter of the base. He further pointed out that the pillar should be surrounded by such an extent of rock as to diminish the force of the waves breaking at its foot. He also proposed that the floor of the lower room of the lighthouse should be 50 feet above the level of the rock, and from thence to the top of the platform 35 feet; making a total height of 85 feet to the platform or gallery. He recommended that argand lights should be employed, with parabolic reflectors; and he suggested for consideration the employment of carburetted hydrogen gas, then coming into extensive use for lighting purposes. The cost of the lighthouse, so constructed, he estimated at about 42,000*l.*

The Commissioners adopted Mr. Rennie's report, and proceeded to Parliament for the requisite powers, which were obtained in the session of 1806; after which (on the 3rd of December following) they unanimously appointed him the chief engineer for conducting the work. At Mr. Rennie's recommendation Mr. Stevenson was appointed the assistant-engineer to superintend the operations on the spot, and he placed under him two able foremen superintendents, Mr. Peter Logan over the masons, and Mr. Francis Watt over the joiners employed upon the lighthouse. Mr. Rennie was then requested to report further, with plans and specifications of the various works in detail; which he prepared and duly submitted to the Board.

In this second report of the 26th December following, Mr. Rennie entered at great length into the description of stone to be used in the building, based upon a personal inspection of the quarries at Mylnefield near Dundee, at Arbroath, and at Aberdeen; and on his recommendation it was determined to use blocks from the Rubieslaw quarry at Aberdeen for the outer, and Dundee stone for the inner masonry. He also repeated his advice, that in carrying out the work, the plan of construction adopted by Smeaton in building the lighthouse on the Eddystone should be mainly followed: one of the few deviations consisting in the substitution of dovetailed pieces of stone for chain bars in the joints both of the walls and the floors. These recommendations having been adopted, Mr. Rennie was authorised to proceed with the requisite preparations for the building; and, after making all due arrangements, and giving his representatives suitable instructions, he left the practical operations to be carried out by them accordingly.*

The whole of the year 1807 was occupied in constructing the necessary vessels, and in erecting the requisite machinery and building-shops at the working yard at Arbroath, which was fixed upon as the most convenient point on the coast for carrying on the land operations. Some progress had been made at the rock itself, where a smith's forge was fixed and a temporary beacon erected, while a floating light, fitted up in an old fishing dogger, was anchored near the reef until the lighthouse could be erected. Preparations had also been made for proceeding with the foundations, the necessary excavations being conducted at considerable peril, in consequence of the violence of the waves and the short period during which the reef was uncovered during each day.

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* A detailed account of the operations was afterwards published by the assistant-engineer, in his interesting work entitled 'An Account of the Bell Rock Lighthouse.' By Robert Stevenson, Civil Engineer. Edinburgh, 1824.

The dangerous nature of the employment may be illustrated by the following brief account of an accident which happened to the workmen on the 2nd of September, before the excavation for the first course had been completed. An additional number of masons had that morning come off from Arbroath in the tender of forty tons, named 'The Smeaton,' and having landed them on the rock, the vessel rode at salvagee, with a crosshead made fast to the floating buoy. The wind rising, the men began to be uneasy as to the security of the 'Smeaton's' riding-ropes, and a party went off in a boat to examine whether she was all secure; but before they could reach the vessel's side they found she had already gone adrift, leaving the greater part of the men upon the reef, in the face of a rising tide.

By the time the 'Smeaton's' crew had got her mainsail set and made a tack towards their companions, she had drifted about three miles to leeward, with both wind and tide against her, and it was clear that she could not possibly make the rock until long after it had been completely covered. There were thirty-two men in all upon the Inchcape, provided with but two boats, capable of carrying only twenty-four persons in fine weather. Mr. Stevenson seems to have behaved with great coolness and presence of mind on the occasion, though he confessed that of the two feelings of hope and despair, the latter largely predominated. Fully persuaded of the peril of the situation, he kept his fears to himself, and allowed the men to continue engrossed with their occupations of boring and excavating.

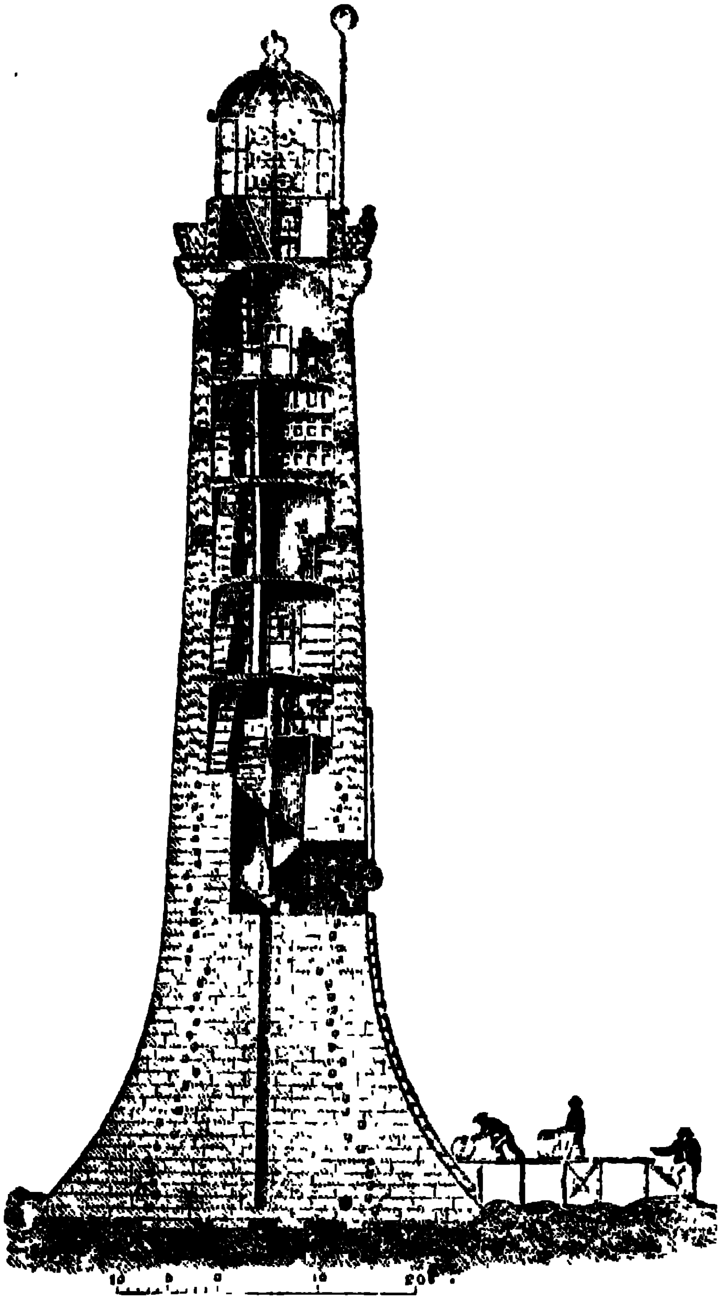
After working for about three hours, the water began to rise along the lower parts of the foundations, and the men were compelled to desist. The forge fire became extinguished; the smith ceased from hammering at his anvil, and the masons from hewing and boring; and when they took up their tools to depart, and looked around, their vessel was not to be seen, and the third of their boats had gone after the 'Smeaton,' which was drifting away in the distance! Not a word was uttered; but the danger of their position was instantly comprehended by all. They looked towards their master in silence; but the anxiety which had been growing in his mind for some time had now become so intense, that he was speechless. When he attempted to speak, his mouth was so parched that his tongue refused utterance. Turning to one of the pools on the rock, he lapped a little water, which gave him relief, though it was salt; but what was his happiness when, on raising his head, some one called out "A boat! a boat!" and sure enough, a large boat was seen through the haze making for them. She proved to be the Bell Rock pilot-boat, which had come off from Arbroath with letters, and her timely arrival doubtless saved the lives of the greater part of the workmen. They were all taken off and landed in safety, though completely drenched and exhausted.

Mr. Rennie, accompanied by his son George, visited the rock on the 5th of October, 1807, the day before the works were suspended for the winter. They came off from Arbroath, and stayed on board the lighthouse yacht all night, where Mr. Stevenson states that he "enjoyed much of Mr. Rennie's interesting conversation, both on general topics and professionally upon the progress of the Bell Rock works, on which he was consulted as chief engineer." On the following morning Mr. Rennie landed to inspect the progress made in the excavation, being received with a display of colours from the beacon and three cheers from the workmen. They continued at work for only about three hours that day, after which the whole working party, accompanied by the chief engineer and his son, the resident engineer, and the foreman of the works, returned to land for the winter.

The preparation of the stone blocks for next summer's operations then proceeded on shore; and by the spring large numbers were dressed, and ready to be floated off. In May, 1808, the excavations on the rock were proceeded with, and on the 10th of July the first stone was laid with considerable ceremony. Mr. Rennie paid his next visit on the 25th of November following, for the purpose of inspecting the work done, and reporting progress to the Commissioners. From his report it appears that three courses of masonry had by that time been laid in a very complete manner. At his suggestion, a modification was adopted in the cement used for the building, and also in the use of the granite blocks delivered from the Aberdeen quarry, some of which had been found defective.

By the end of 1809, at our engineer's next visit of inspection, the tower had been built to a height of 30 feet, and was comparatively secure against the effects of the most violent seas. In his report to the Commissioners he stated that he found that the form of slope which he had adopted for the base of the tower, as well as the curve of the building, fully answered his expectations—that they presented comparatively small obstruction to the roll of the waves, which played round the column with ease—and he expressed the opinion that the lighthouse, when finished, "would be found to be the most perfect work of its kind." In his report he recommended a modification in the details of the upper part of the building. In dovetailing the stones together, the method employed at the Eddystone had up to this point been followed; but from the top of the staircase he proposed that a somewhat different plan should be adopted.

"The stone floors in the Eddystone," he said, "were formed by an arch in the shape of a dome springing from the surrounding walls, to strengthen which chain bars were laid in the walls. 'I propose that these should be done with large stones radiating from a circular block in the middle, to which their interior ends are to be dovetailed as well as the radiated joints, and these connected to the surrounding walls by means of a circular dowel. By this means the lateral pressure on the walls will be



Section of Bell Rock Lighthouse.

removed, the whole connected together as one mass, and no chain-bars will be wanted except under the cornice. Thus the whole will be like a solid block of stone ex cavated for the residence of the lightkeepers, stores, &c. He concluded with some practical advice as to the construction of the lantern after an improved method which he proposed, in order that it might be in readiness in the course of the ensuing summer, by which time he anticipated that the building would be ready for use if the weather proved favourable. These recommendations were adopted, and the work having proceeded satisfactorily, the whole was completed by the end of 1810, and the light was regularly exhibited after the 1st of February, 1811.

When finished, the tower was 10 feet higher than the original design, being 95½ feet to the top of the cornice, and 127 feet to the top of the lantern. The additional height to which Mr. Rennie thought it necessary to carry the lighthouse during its construction, had the effect of raising the total cost to 61,331*l.*; but he believed that the increased outlay would be fully justified by the greater security of the lighthouse and its increased efficiency for the purpose for which it was intended.

Notwithstanding the facts which we have stated, showing that Mr. Rennie acted throughout as the chief engineer of the lighthouse—that he furnished the design, arranged the details of the building, settled the kind of materials to be used, down even to the mode of mixing the mortar, and from time to time made various alterations and modifications in the plans of the work during its progress, with the sanction of the Commissioners—his name has not usually been identified with the erection of the structure; the credit having been almost exclusively given to Mr. Robert Stevenson, the resident engineer,—arising, no doubt, from the circumstance of Mr. Rennie being in a great measure ignored in the 'Account of the Bell Rock Lighthouse,' published by Mr. Stevenson several years after the death of Mr. Rennie.

The following account was given by Mr. Rennie himself, in a letter to Matthew Boulton of Birming ham,* relative to his own and Mr. Stevenson's connection with the plans and erection of the lighthouse:—

"Mr. Robert Stevenson was bred a tinsmith and lamp-maker, in which line he was employed by a Mr. Thomas Smith, a considerable manufacturer in Edinburgh, who had the care of the reflectors and lamps belonging to the Commissioners of Northern Lights. While in Smith's employment Stevenson married his daughter, and Smith, advancing in years, employed Stevenson to look after the Northern Lights. This he did for several years. When Smith declined the situation, Stevenson was elected in his place.

"When the Bell Rock Lighthouse was erected, Stevenson was employed to superintend the whole. A regular head mason and carpenter were employed under him. The original plans were made by me, and the work was visited by me from time to time during its progress. When the work was completed, Stevenson considered that he had acquired sufficient knowledge to start as a civil engineer, and in that line he has been most indefatigable in looking after employment, by writing and applying wherever he thought there was a chance of success.

"He has assumed the merit of applying coloured glass to lighthouses, of which Huddart was the actual inventor, and I have no doubt that he will also assume the whole merit of planning and erecting the Bell Rock Lighthouse, if he has not already done so. I am told that few weeks pass without a puff or two in his favour in the Edinburgh papers" * * *

Mr. Stevenson was unquestionably entitled to great merit for the able manner in which he performed his duties as a superintendent in connection with the building of the Lighthouse. Mr. Rennie was always ready to acknowledge this. But had any failure occurred in consequence of a defect in the plans, Mr. Rennie, and not Mr.

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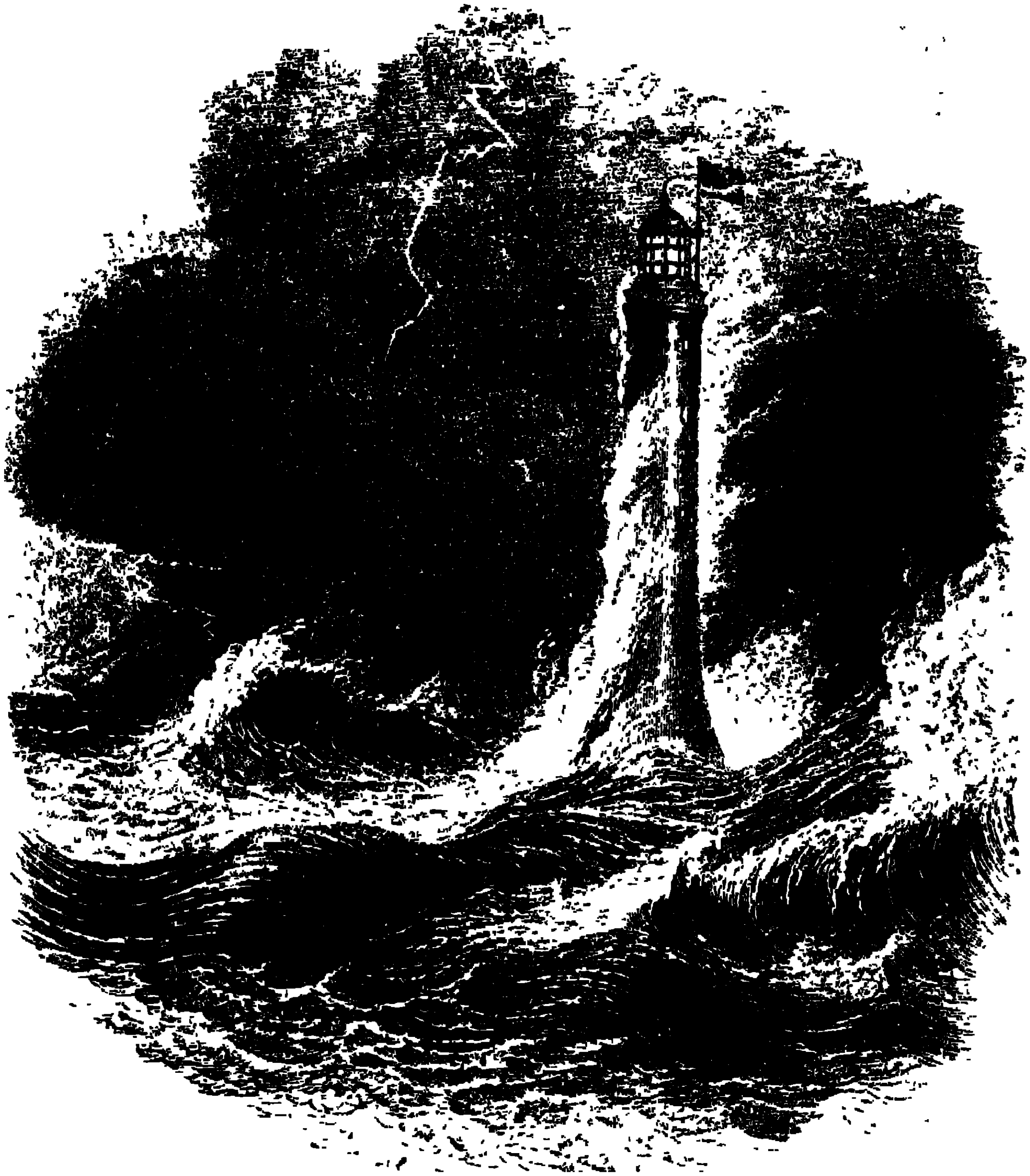
* Letter dated the 12th March, 1811 Boulton MSS.

Stevenson, would have been held responsible. As, however, the Lighthouse proved a success, it is but fair that the chief engineer should not be deprived of the merit which unquestionably belonged to him. It is a matter of impossibility that engineers in extensive practice should personally superintend the various structures designed



The Bell Rock Lighthouse. [By Percival Skelton.]

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by them, and which are proceeding at the same time in different parts of the country. Hence the appointment, at their recommendation, of superintendents or resident engineers, whose business it is to see that the details of the design are faithfully carried out, and that the work is executed in all respects according to the chief engineer's designs and instructions.

To take two instances—Telford's Menai Bridge and Stephenson's Britannia Bridge—in the former of which cases Mr. Provis was appointed resident engineer, and in the latter Mr. Edwin Clarke. Both of these gentlemen afterwards published detailed histories of these works; but neither of them ignored the chief engineer, nor did they claim the exclusive merit of having been the successful erectors of these magnificent structures.

During Mr. Rennie's lifetime various notices were published, claiming for Mr. Stevenson the sole credit of having designed and erected the lighthouse. At this Mr. Rennie was naturally annoyed; and the more so when he learnt that Mr. Stevenson was about to "write a book" without communicating with him on the subject. "I have no wish," he says, in a letter to a friend, "to prevent his writing a book. If he details the truth fairly and impartially, I am satisfied. I do not wish to arrogate to myself any more than is justly my due, and I do not want to degrade him. If he writes what is not true, he will only expose himself. I bethink me of what Job said, 'Oh that mine enemy would write a book!'" The volume, however, was not published until three years after Rennie's death; and it was not until the publication of Sir John's work on Breakwaters, that his father's claims as chief and responsible engineer of the lighthouse were fairly asserted and afterwards fully and clearly established.*

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* The correspondence which took place on the subject will be found recorded in the 'Civil Engineer and Architect's Journal,' vol. xii., 1849.

CHAPTER VIII.

MR. RENNIE'S DOCKS AND HARBOURS.

THE growth of the shipping business, and the increase in our home and foreign commerce, led to numerous improvements in the harbours of Britain about the beginning of the present century. The natural facilities of even the most favourably situated ports, though to some extent improved by art, no longer sufficed for the accommodation of their trade. Comparatively little had as yet been done to improve the port of London itself, the great focus of the maritime and commercial industry of Britain.* It is true, that its noble river the Thames provided a great amount of shipping room between Millwall and London Bridge; but the rise and fall of the tide twice in every day, and the great exposure of the vessels lying in the river to risks of collisions, and other drawbacks, were felt to be evils which the shipping interest found it necessary to remedy.

Besides the crowding of the river by ships and lighters —the larger vessels having to anchor in the middle of the

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* The increase in the trade of London is exhibited by the following abstract of vessels entered at the port at different periods since the beginning of last century:—

YEARS	BRITISH		FOREIGN		COLLIERS AND COASTERS.	
	Vessels	Tonnage	Vessels	Tonnage	Vessels	Tonnage.
1702	839	90,040	496	76,995	No return.	No return.
1751	1498	198,023	184	36,346	Do	Do.
1798	1619	397,096	1777	229 991	10,133	1,250,449
1860	6320	1,828,911	4857	1 152,499	18,346	3,152 853

stream as low as Blackwall, from which their cargoes were lightered to the warehouses higher up the Thames—the warehouse accommodation was found very inadequate in extent, as well as difficult of access. It took not less than a month to deliver an East Indiaman of 800 tons of her cargo; while a coasting ship of 350 tons required eight days in summer and fourteen in winter. The quantity of plunder also, stolen from ships lying in the river was something extraordinary. Mr. Colquhoun, the police magistrate, estimated the annual depredations on the foreign and coasting trade to amount to not less than half-a-million sterling!

The lightermen, watermen, labourers, sailors, mates and sometimes captains, and often the officers of the revenue, were leagued together in a system of pilfering valuables from the ships while lying at anchor in the river, or from the barges into which the goods had been transferred. Mr. Colquhoun stated the number of pilferers and thieves to amount to 10,850; and the number of receivers to 550.

The plunderers were divided into various gangs. There were the *River Pirates*, a set of desperate and depraved characters, who attacked the ships while lying at anchor at night. They would weigh the ship's anchor, hoist it into their boat, set the ship adrift, and then make clear off; or, they would mount the ship's side while the crew were asleep, cut away bags of cotton, cordage, spars, oars, throw them into their boats, and make away. They were usually armed, and defended themselves by force when attacked. They carried on their operations by day as well as night, and they were usually permitted to escape by the other labourers on the river, who were for the most part as bad as themselves.

There were also the *Night Plunderers*—mostly watermen, who worked together in gangs of four or five in number, and plundered the lighters and other craft into which goods had been stored. They were usually in league with the watchmen of the lighters, with whom they shared the plunder. But sometimes the watchmen did not allow their own lighters to be plundered, but would point out others which were without any guard; and in this way, while appearing honest themselves, they shared in the general system of thievery.

The *Light Horsemen* were the nightly plunderers of West India ships. There was an arrangement between them, the mates of the ships, and the criminal receivers, by which an incredible quantity of sugar and other articles was abstracted from the ships in the river. The mates claimed the sweepings, that is, the drainings of sugars which remained in the hold after the cargo had been discharged. The connivance of the revenue officers was necessary in order to get these sweepings landed. A payment of from 30 to 50 guineas was sufficient to allow the Light Horsemen—who consisted of coopers, watermen, lumpers, and receivers—to get on board at night for the sweepings. They then opened as many hogsheads of sugar and bags of coffee as possible, and plundered the ship without control. The ships subject to this species of depredation were known as *Game Ships*, and they frequently suffered the loss of as much as from fifteen to twenty hogsheads of sugar, with corresponding quantities of coffee and rum.

The *Heavy Horsemen*, or lumpers—who often worked, or desired to work, on board of West India ships without wages,—generally connived with the mates or revenue officers to carry away large quantities of stuff in their dress. They had an under-waistcoat, containing pockets all round, called a Jemie; and long bags, pouches, and socks, tied to their legs and thighs under their trousers, in which they concealed sugar, coffee, pimento, ginger, rum, and other articles. When employed upon a game ship, these thieves used to divide from three to four guineas every night from the produce of their plunder, independent of the hush-money paid to the mates and revenue officers.

Then there were the *Game Watermen*, who would wait upon West India ships in course of discharge, and take on their backs bags of sugar, coffee, and such like, handed to them by the lumpers and others in the delivery of the cargo. The game watermen divided with the lumpers and others the money obtained from the receivers of the stolen goods.

Besides these river thieves and pirates, there were also the *Game Lightermen*, who concealed in the lockers of their lighters considerable quantities of valuable goods, for the purpose of selling them; the *Mud Larks*, who prowled about in the mud at low water, under the quarters of West India ships, pretending to pick up old ropes, iron, and such like, but really waiting to have bags of sugar, coffee, rum, and pimento, lowered down to them from the thieves on board the ship; the *Revenue Officers*, who were paid a very small sum for their services, and eked it out with plunder; the *Scuffle-Hunters*, who stole promiscuously from the crowded quays and wharves where the goods were discharging; and the *Copemen*, or receivers of stolen property, who were themselves often parties to the robbing of ships in company of the light horsemen.

These criminals not only plundered in gangs, but they had the audacity to form a club for the purpose of resisting the attacks made upon them, under the powers of an Act passed in 1792,* commonly called the Bumboat Act; and by this means many of the scoundrels apprehended, escaped the punishment due to their crimes. As a proof, amongst others, of the enormous extent of the river plunder, the convictions for misdemeanors between August 1792, and August 1799, exceeded 2200; of which number about 2000 culprits paid the penalties - partly from their own resources, but chiefly, it is believed, from the funds of the club—amounting in all to about 4000*l.*, in the course of seven years.†

The Thames Police was established, in 1798, for the purpose of checking this system of wholesale depredation; but, so long as the goods were conveyed from the ship's side in open lighters, and the open quays formed the principal shore accommodation—sugar hogsheads, barrels, tubs, baskets, boxes, bales, and other packages, being piled up in confusion on every available foot of space—it was clear that mere police regulations would be unequal to meet the difficulty. It was also found that the confused manner in which the imports were brought ashore led to a vast amount of smuggling, by which the honest merchant was placed at a considerable disadvantage, at the same time that the revenue was cheated. The Government, therefore, for the sake of its income, and the traders for the security of their merchandise, alike desired to provide an effectual remedy for these evils.

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* 2 George III., cap 28.

† P. Colquhoun, LL.D., 'Treatise on the Police of the Metropolis.' [6th Ed., 237.]

Mr. Rennie was consulted on the subject in 1798, and requested to devise a plan. Before that time, various methods had been suggested, such as quays and warehouses, with jetties, along the river on both sides; but all these eventually gave place to that of floating docks or basins communicating with the river, surrounded with quays and warehouses, shut in by a lofty enclosure-wall, so that the whole of the contained vessels and their merchandise should be placed, as it were, under lock and key. By such a method it was believed the goods could be loaded and unloaded with the greatest economy and despatch, whilst the Customs duties would be levied with facility, at the same time that the property of the merchants was effectually protected against depredation.

About the middle of last century a small dock had existed on the Thames, called the Greenland Dock; but it was of very limited capacity, and was only used by whaling vessels. Docks had existed at Liverpool for a considerable period; so that there was no novelty in the idea of providing accommodation of a similar kind on the Thames, though it is certainly remarkable that, with the extraordinary trade of the metropolis, the expedient should not have been adopted at a much earlier period.

The first docks constructed on the Thames were the West India Docks, and the London Docks. The former the isthmus that formerly connected the Isle of Dogs with Poplar, and were designed and constructed by Mr. William Jessop.* At the same time that the West India Docks were in course of construction, a company was formed by the London merchants, in 1800, for the purpose of constructing docks, at a point as near the Exchange as possible, for the accommodation of general merchandise; and of this scheme Mr. Rennie was appointed the engineer. Several designs were proposed for consideration, on a scale more or less extensive and alternative plans were submitted

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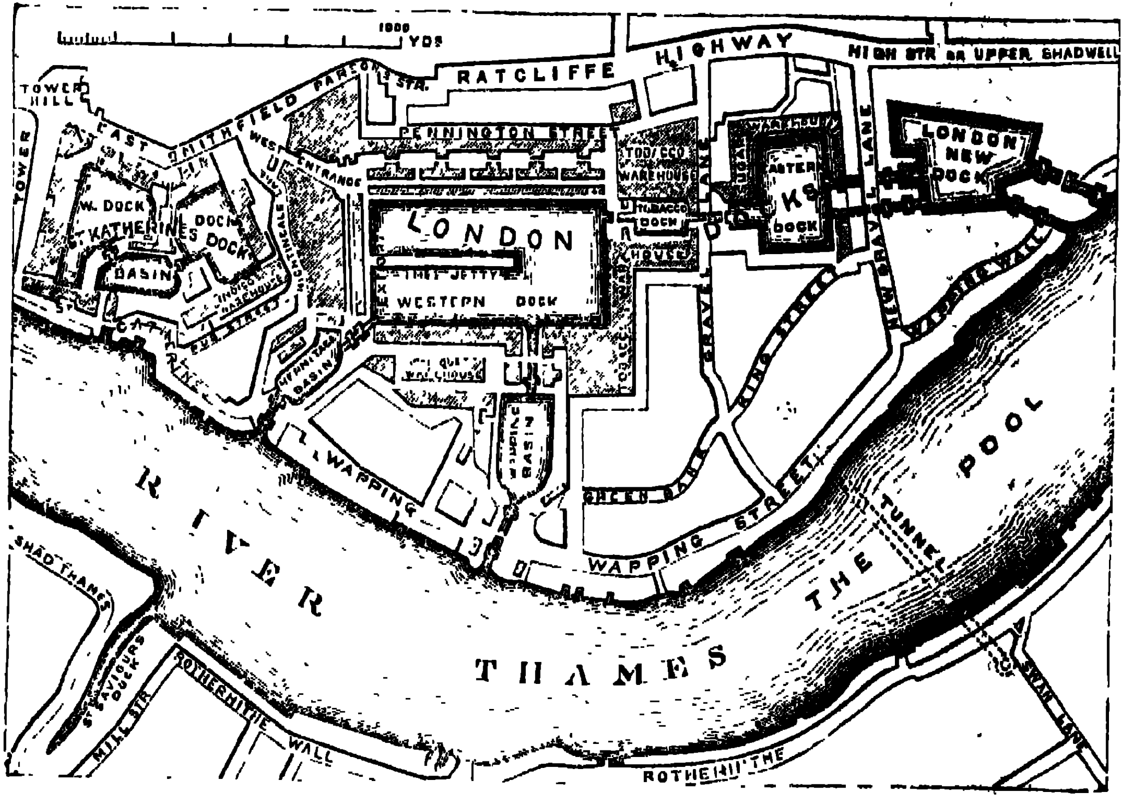
* Mr. Jessop was among the most eminent engineers of his day. His father was engaged under Smeaton in the building of the Eddystone Lighthouse, and, dying in 1761, he left the guardianship of his family to Mr. Smeaton, who adopted William as his pupil, and carefully brought him up to the same profession. Jessop continued with Smeaton for about ten years; and, after leaving him, he was engaged successively on the Aire and Calder, the Calder and Hebble, and the Trent Navigations. He also executed the Cromford and the Nottingham Canals, the Loughborough and Leicester, and the Horncastle Navigations; but the most extensive and important of his works of this kind was the Grand Junction Canal, by which the whole of the north-western inland navigation of the kingdom was brought into direct connection with the metropolis. He was also employed as engineer for the Caledonian Canal, in which he was succeeded by Telford, who carried out the work. Mr. Jessop was the engineer of the West India Docks (1800-2) and of the Bristol Docks (1803-8), both works of great importance. He was the first engineer employed to lay out and construct railroads, as a branch of his profession; the Croydon and Merstham Railroad, worked by donkeys and mules, having been constructed by him as early as 1803. He also laid down short railways in connection with his canals in Derbyshire, Yorkshire, and Nottinghamshire. During the later years of his life he was much afflicted by paralysis, and died in 1814.

William Jessop, C.E.

to the directors. Suggestions were also invited, which were afterwards worked up into more complete designs. As the future trade of London was an unknown quantity, Mr. Rennie wisely provided for the extension of the docks, as circumstances might afterwards require.

In carrying out the London Docks it was deemed advisable, in the first instance, to limit the access to the present Middle River Entrance at Bell Dock, 150 feet long and 40 feet wide, with the cill laid five feet below low water of spring tides. The entrance lock communicated with a capacious entrance basin, called the Wapping Basin, covering a space of three acres, and this again with the great basin called the Western Dock, 1260 feet long and 960 feet wide, covering a surface of 20 acres. The bottom of the dock was laid 20 feet below the level of high water of an 18 feet tide. The quays next to the river were five feet above high water, increasing to nine feet at the Great



Plan of London Docks.

Dock. From the east side of the latter it was ultimately proposed to make two or more docks, communicating with each other and with a larger and deeper entrance lower down the river at Shadwell; all of which works have since been carried out.

As the site of the Docks was previously in a great measure occupied by houses, considerable time necessarily elapsed before these could be purchased and cleared away; so that the works were not commenced until the spring of 1801, when two steam-engines were erected, of 50-horse power each, for pumping the water, and three minor engines for other purposes, such as grinding mortar, working the pile-engine, and landing materials from the jetty – an application of steam power as an economist of labour which Mr. Rennie was among the first to introduce in the execution of such works. The coffer-dams for the main entrance, and the excavation of the Docks, were begun in the spring of 1802;* after which time the works were carried forward with great vigour until their completion on the 30th of January, 1805, when they were opened with considerable ceremony.

At a subsequent period Mr. Rennie designed the present westernmost or Hermitage entrance lock and basin, the former of which is 150 feet long and 38 feet wide, with the cill laid two feet below low water of spring tides; the basin and main dock covering a surface of one acre and a quarter. Another small dock of one acre was afterwards added on the north-east side of the Great Basin, exclusively devoted to the tobacco trade; and it was ultimately extended to the Thames at Shadwell, as contemplated in the original design.

After the docks had been opened for trade, Mr. Rennie gave his careful attention to the working details, and he was accustomed from time to time to make suggestions with a view to increased despatch and economy in the conduct of the business. Thus, in 1808, he recommended that the whole of the lifting-cranes in the Docks should be worked by the power of a steam engine, instead of by human or horse labour. He estimated that the saving thus effected, in the case of only twenty-six cranes, would amount to at least 1500*l.* a-year, besides ensuring greater regularity and despatch of work; and, if applied to the whole of the cranes along the Docks and in the warehouses, a much greater annual saving might be anticipated. It was, however, regarded as too bold an innovation for the time; and for many years the cranes in the London Docks continued to be worked by hand labour, at a great waste of time and money, as well as loss of business.

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* For further particulars as to these docks see Sir John Rennie's 'British and Foreign Harbours Art. "London Docks."

Another of Mr. Rennie's valuable suggestions, with a view to greater economy, was the adoption of tramways all round the quays, provided with trucks, by means of which the transfer of goods from one part of the Dock to another might be effected with the greatest ease and in the least possible time. But this, too, was long disregarded. Labour-saving processes were then less valued than they are now. The application and uses of machines were as yet imperfectly understood, and there were in most quarters powerful prejudices to be overcome before they could be introduced. The goods in the London Docks are still hauled in trollies, waggons, or hand-barrows from ship to ship, or from the vessels to the respective bonded warehouses; and it still remains matter of surprise that a system so clumsy, so wasteful of time, so obstructive to rapid loading and unloading in dock, should be permitted to continue.

Shortly after these works were set on foot, and when the great importance and economy of floating docks began to be recognised by commercial men, another project of a similar character was started, to provide accommodation exclusively for vessels of the East India Company, of from 1000 to 1800 tons burden. A company was formed for the purpose, and an Act was obtained in 1803, the site selected being immediately to the west of the river Lea, near the point at which it enters the Thames; and where at that time there were two small floating basins or docks, provided with wooden locks, and surrounded with wooden walls, called the Brunswick and Perry's Docks. These it was determined to purchase and include in the proposed new docks, of which, however, they formed but a small part.

Mr. Rennie and Mr. Ralph Walker were associated as engineers in carrying the works into execution, and they were finished and opened for business on the 4th of August, 1806. They consisted of an entrance lock into the Thames 210 feet long and 47 feet wide, with the cill laid 7 feet below low water of spring tides. This lock is connected with a triangular entrance basin, covering a space of 4[illegible] acres, on the west side of which it communicates by a lock with a dock expressly provided for vessels outward bound, called the Export Dock, 760 feet long and 463 feet wide, covering a surface of 8¼ acres. At the north end of the entrance basin is the Import Dock, 1410 feet long and 463 feet wide, covering a surface of 18¾ acres. The depth of these basins is 22 feet below high water of ordinary spring tides. The total surface of dock room, including quays, sheds, and warehouses, is about 55 acres.

The original capital of the East India Dock Company was 660,000*l.*; but Mr. Rennie constructed and completed the Docks for a sum considerably within that amount. Eventually they were united to the West India Docks, under the joint directorate of the East and West India Dock Company.* Mr. Rennie also introduced into these

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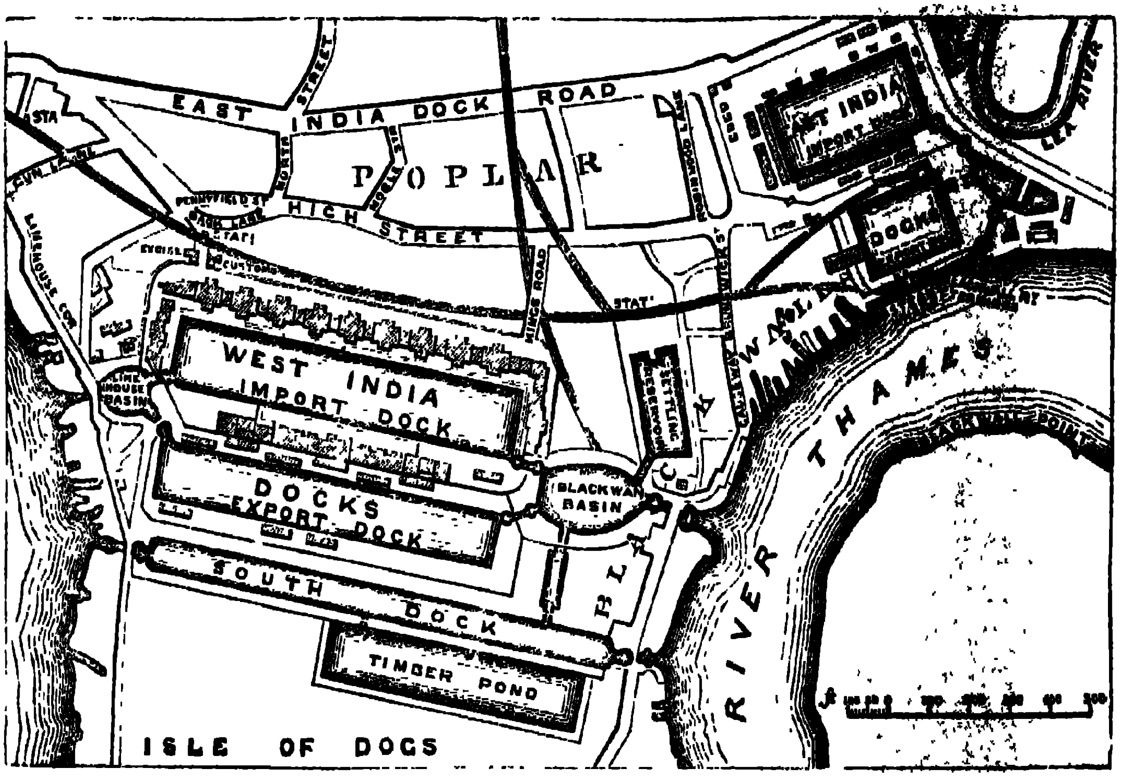
* Among the improvements adopted by Mr. Rennie in these docks may be mentioned the employment of cast iron, then an altogether novel expedient, for the roofing of the sheds. One of these, erected by him in 1813, was 1300 feet long and 29 feet 6 inches in [illegible] supported on cast-iron columns 7½ inches in diameter at bottom and 5¼ at top. Another, still more capacious, of 54 feet clear span between the supports, was erected by him over the mahogany warehouses in 1817. He also introduced an entirely new description of iron cranes, first employing wheelwork in con

Docks many improved methods of working; his machinery, invented by him for transporting immense blocks of mahogany by a system of railways and locomotive cranes, having, in the first six months, effected a saving in men's wages more than sufficient to defray their entire original cost, besides the increased expedition in the conduct of the whole Dock business.



Plan of East and West India Docks.

Some of Mr. Rennie's harbour works at other places were of considerable magnitude and importance; the growing trade of the country leading to his frequent employment in constructing new harbours, or extending and improving

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nection with them, by which they worked much more easily and at a great increase of power. He entirely re-arranged the working of the mahogany sheds, greatly to the despatch of business and the economy of labour. His quick observation enabled him to point out new and improved methods of despatching work, even to those who were daily occupied in the docks, but whose eyes had probably become familiar with hurry-scurry and confusion.

old ones. In almost every instance he had the greatest possible difficulty in inducing the persons locally interested to provide harbour space sufficiently extensive as well as secure. When asked to give his advice on such questions, he began with making numerous practical inquiries on the spot; he surveyed the adjacent coast, took soundings all round the proposed harbourage, noted the set of the currents, the direction of the prevailing winds, the force and action of the land streams, and the operations of the scour of the tides upon the shore.

He also inquired into the trade to be accommodated, the probability of its expansion or otherwise, and prepared his plans accordingly. Writing to Mr. Foster, of Liverpool, in 1810, he said, "It seems to me that your merchants are much less liberal in their ideas than is generally supposed. The account you give me furnishes another strong proof of the necessity of enlarging your scale of docks." Adverting to another scheme on which he had been consulted, he added, "It is my intention to impress upon the minds of the promoters the necessity for a much larger scale of docks than is proposed; and though they may blame me now, they will thank me afterwards; as larger accommodation will not only afford great and immediate relief to the shipping now, but will save the expenditure of much money hereafter." *

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* The Prince's Dock at Liverpool was constructed after Mr. Rennie's plans; but the greater part of the dock accommodation at that port was provided under the direction of the late Mr. Jesse Hartley. Mr. Hartley was a native of the North Riding of Yorkshire, where his father held the position of Bridgemaster; and his son, after receiving an ordinary education, served his apprenticeship as a stonemason, and worked at the building of Boroughbridge. Subsequently, he succeeded his father as Bridgemaster, which he continued to retain, until his removal to Liverpool, when he received the appointment of engineer to the Dock Committee. During the period in which he held the office of dock engineer, Mr. Hartley altered or entirely constructed every dock belonging to the town. He was also engineer to the Bolton and Manchester Railway and Canal, and consulting engineer for the Dee Bridge at Chester, the centering for which was considered a triumph of engineering skill and ability.

As early as 1793 Mr Rennie was employed [illegible] Commissioners of British Fisheries to report as to [illegible] best means of improving the harbour of Wick,—the [illegible] haven (capable of affording shelter for ships in certain states of the wind) which was to be found along an extent of 120 miles of rock-bound coast. In his masterly report he boldly proposed to abandon the old system of jetties and to make an entirely new harbour beyond the bar; thus at once getting rid of this great and dangerous obstacle to improvement, securing at the same time greater depth of water, better shelter, and the means of easier access and departure for vessels of all burdens.

In order to accommodate the trade of Wick, he recommended that a canal should be made from the new harbour, having a basin at its termination in the town, where vessels would be enabled to float, and to load and unload at all times. He also proposed an effective plan of sluicing, with the view of scouring the outer harbour when necessary. It is much to be regretted that this plan was not carried out and that so important a national work has been postponed almost until our own day, nor does the plan since adopted, though exceedingly costly, seem calculated to secure the objects which would have been obtained by executing Mr Rennie's more comprehensive yet much more economical design.

He was consulted about the same time respecting the improvement of the harbour of Aberdeen, but though want of means then prevented his recommendations from being acted on, his report * produced a salutary effect in pointing out the true mode of dealing with a difficult subject, and most of his suggestions have since been carried out by other engineers.

Of still greater importance was his report on the improvement of the navigation of the river Clyde, for the

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* See Sir John Rennie's 'British and Foreign Harbours,' Art. "Aberdeen."

accommodation of the rapidly increasing trade of Glasgow. Perhaps in no river have the alterations, executed after well-devised plans, been more extraordinary than in this. Less than a century ago, the Clyde at Glasgow was accessible only to herring-boats, whereas now it floats down with every tide vessels of thousands of tons burden, capable of wrestling with the storms of the Atlantic. Watt, Smeaton, and Golborne had been consulted at different times, and various improvements were suggested by them. Watt laid out a ship-canal from Glasgow to the sea. Smeaton proposed to construct a dam and lock at Marlin Ford, so as to allow vessels drawing only four feet of water to pass up to the quay at the Broomielaw.

The clearing out of the channel by artificial means was, however, found the most effectual method of opening up the navigation of the river, and at length all other plans have given way to this. Golborne had run out jetties at various points, by which the scour of the tide had been so directed that considerably greater depth had been secured.

Mr. Rennie examined the entire river below Glasgow in 9, and the result was his elaborate report of that year. He recommended numerous additions to the jetties, as well as many improvements in their direction. He also advised that a system of dredging should be commenced, which was attended with the best possible results; and the same course having been followed by succeeding engineers, the Clyde has now become one of the busiest navigable thoroughfares in the world. The plan which Rennie shortly after prepared and submitted, of a range of commodious docks along both banks of the river at the Broomielaw, showed his sagacity and foresight in an eminent degree; but unhappily it was considered too bold, and perhaps too ly, and it was not then carried out.*

Mr. Rennie proposed to form two docks on the Broomielaw side of the river—one 1850 feet long and 160 feet wide, with two entrances, and another 900 feet long and 200 feet wide, with a third

At the opposite end of the island he was consulted (in 1796) as to the best method of improving the harbour of Torquay, and he submitted a series of able plans, only a small part of which were carried into effect. Shortly after (in 1797) we find him inspecting the sluicing arrangements of the harbour then under construction at Grimsby, when he furnished a plan of the great lock which it was found necessary to place at the entrance of the canal leading to the dock, and which was in his opinion indispensable for scouring the harbour entrance and keeping it clear of silt. This lock was executed according to his plans by the local engineer; but it appeared that sufficient precautions had not been taken in founding and proportioning the dimensions of the retaining walls, on which Mr. Rennie had not been requested to give an opinion, the work appearing to be of so simple and ordinary a character.

Shortly after the building had been begun, a considerable portion of the lock walls gave way, and Rennie was again sent for to inquire and report as to the cause of the failure. He found that the defect lay in the nature of the ground on which the foundation was built, which was so soft that it would not bear the weight of solid walls of the ordinary construction. Always ready with an expedient to meet a difficulty, he directed that, without diminishing the quantity of material employed, it should

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dock upon the Windmill Croft, on the south side of the river, 300 feet long and 200 feet wide; the whole presenting a total length of quayage of 6120 feet, besides a river quay wall 1150 feet long. This magnificent plan, proposed more than half a century since, viewed by the experience of this day, shows how clearly Rennie anticipated the commercial growth and manufacturing prosperity of Glasgow, for which these projected docks would have afforded ample accommodation, at an estimated capital cost (at the time the plans were made) of only 130,000*l*. What would not Glasgow give now to have the benefit of Rennie's docks? Indeed it is remarkable that, to this day, so little has been done to realize his idea, and to provide dock accommodation for the trade of the Clyde, which is now quite as much needed as the same kind of accommodation was in the Thames at the beginning of the present century.

be distributed over a greater base, for the purpose of securing a larger bearing surface. With this object he prepared his plan of the requisite structure, adopting the expedient of *hollow walls*, which he afterwards employed so extensively in his pier and harbour works. They not only bore upon a larger base, but were found even stronger than solid walls containing an equal quantity of material. Those at Grimsby have stood firm until the present day. The contrivance was thought so valuable, that some years after Mr. Rennie had invented it, Sir Samuel Bentham (in 1811) took out a patent for the plan; but of this Mr. Rennie took no notice, having himself, as we have seen, been the original inventor of the process. Indeed, his attention had long before this time been directed to the best form of walls for resisting the pressure of water; and, as early as the year 1793, we find him recommending the adoption of curved walls, in place of the inclined straight-faced walls with perpendicular back, as formerly adopted.*

Another important harbour on which Mr. Rennie was early employed was that of Holyhead, situated at the point of the island of Anglesea, nearest to the Irish capital. Although so conveniently placed for purposes of embarkation, everything had as yet been left to nature, which had only provided plenty of deep water and many bold rocks. But Holyhead had neither pier nor jetty, nor any convenience whatever adapting it for harbour uses. Besides, the place was almost inaccessible from inland by reason of narrow, rugged, and in many places almost precipitous roads. The dangerous ferries at Conway and Menai also presented serious obstacles to travelling by that route; and hence the port of Liverpool, and Park Gate on the Dee near Chester, continued to be the principal places of embarkation for persons proceeding to Ireland, until the beginning of the present century.

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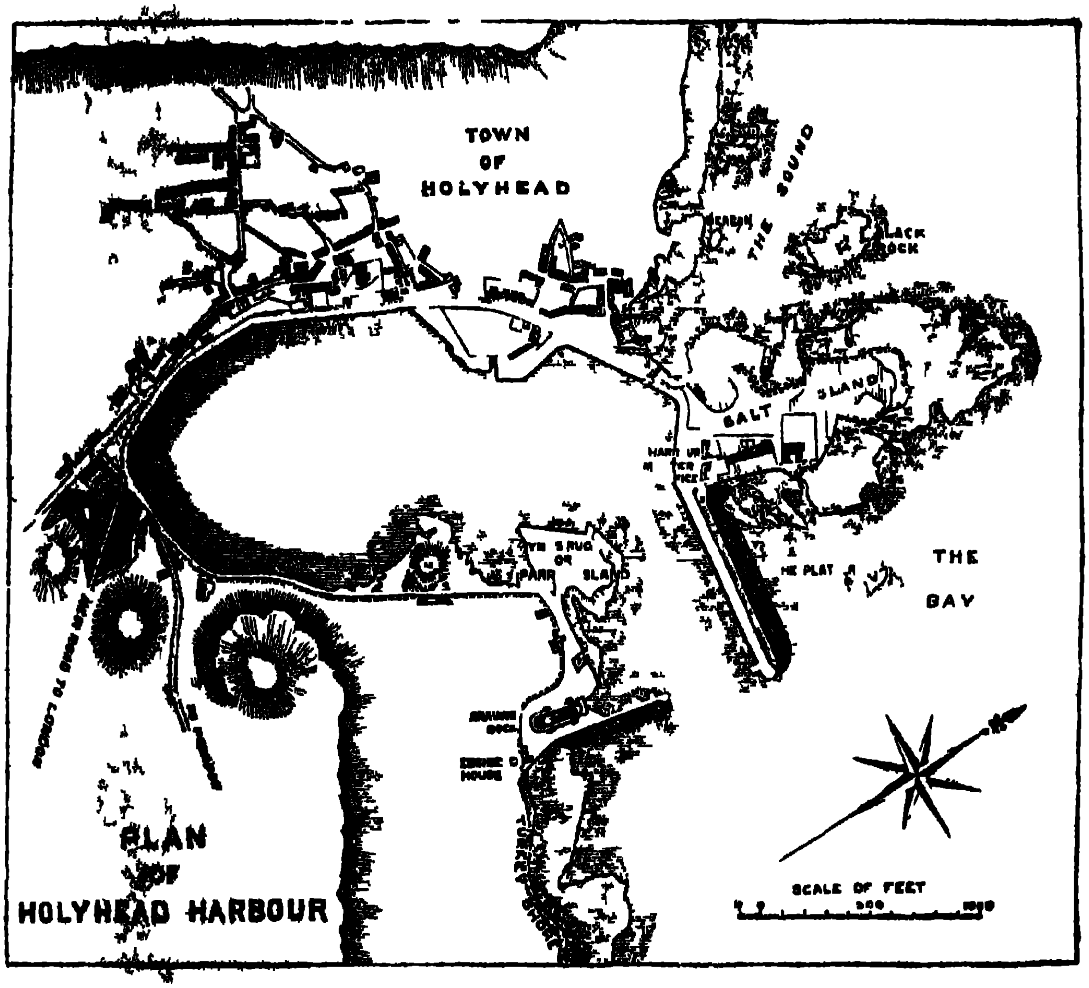
* The occasion on which this plan was first recommended was in Mr. Rennie's report (1793) on the Hutchison Bridge across the Clyde. That bridge, erected by another engineer, fell down on the removal of the centres, on which Mr. Rennie was sent for, post haste, by the Lord Provost and magistrates of Glasgow, to confer with them on the subject; and his advice as to the rebuilding of the bridge on another site was subsequently adopted. It appeared, from an inspection of the ruined piers, that a breast or quay wall had been built on the south side of the river, and to the west of the bridge, which had not been executed according to contract. The report stated:—"The above walls should be enlarged in their dimensions and altered in their construction; they ought to be carried at least to the level of the river bed, and made five feet thick at the base next to the bridge, and four feet thick at the top, battering one-fifth of their height *in a curvilinear form*, the beds of the stones being *radiated to the centre of the curve*; as the height lessens, the dimensions of the walls may be diminished in the same proportion, and, if built as above described, I have no doubt of the works being permanent."

When the Act of Union was passed, the Government determined to bring the two countries into closer communication with each other; first by means of convenient roads through North Wales, and next by capacious harbours at Holyhead on the one coast and at Kingstown on the other. In the year 1802, Mr. Rennie was requested to report upon the subject, and he proceeded to Wales for the purpose of examining the Conway and Menai ferries, and the capabilities of Holyhead as a port. It was on that occasion that he recommended the construction of the permanent fixed bridges across both Straits after the plans already referred to. Nothing was, however, done towards carrying out his suggestions, and the whole question slept until the year 1809, when he was requested by Government to prepare plans of a harbour at Holyhead, as the first step towards the desired improvement; and his design having been approved, the works were begun in the following year.

The form of the harbour of Holyhead has been determined, in a great measure, by the cliffs which overhang the sea, and on the verge of which stand the ancient church and cemetery of the town. The works designed by Mr. Rennie consisted of a pier 1150 feet long, extending in a direction nearly due east from the inner side of Salt Island, which is separated by a narrow channel from the main island of Holyhead The pier terminated at a depth of about 14 feet at low water of spring tides At 80 feet distant from the extremity of the main pier there was a jetty 60 feet long, carried out at right angles to its inner face, to check any swell which might come



round the pier-head from entering the harbour, and to throw it upon the opposite shore The roadway was 50 feet wide, and 8 feet above the level of high water of spring tides, the parapet being 7 feet higher. The outer or sea side of the pier was formed by a flat paved slope of rough stone, laid at an inclination of 5 to 1 The parapet wall was curved on the face one-fifth of the height, the thickness of the masonry being 10 feet upon the average, strengthened at the back by strong counterforts, at the regular distance of 15 feet apart. The foundation of this wall was laid below low water by means of long stones, inclined to each other, in the same manner as at

Holyhead Harbour [By R P Leitch]

Howth Harbour, where the plan had been found to answer remarkably well. The centre of the pier was composed of loose rubble, taken from the adjacent shore, packed solidly; the outside being paved with large angular blocks varying from one to ten tons in weight, well wedged together. The inside of the parapet was built of solid masonry. The pier-head and jetty were founded below low water by means of the diving-bell. The works were begun in 1810 and finished in 1824, and during their progress a small pier was run out from the Pibeo rock on the opposite shore, 550 feet long, leaving an opening between it and the main pier of 420 feet. This pier was provided with a jetty on the inside, similar to that on the main pier, composed of the same kind of materials, and finished in like manner. Within it was a small dry dock for merchant vessels. The total low-water space covered by these two piers was about six acres; but there was more than double that area at high water, besides a large shallow space of about thirty acres for timber.

In conformity with his usual practice, Mr. Rennie so laid out this harbour as to be capable of extension on the same principles, according as the trade of the port might require. Part of his original design was to devote a large space in the inner portion of the bay, which is dry at low water, to a wet dock of 23 acres. Had this been carried out, it would have proved of immense advantage to the numerous land-bound vessels which have occasion to put into the port. His original plan also contemplated a pier extending from the outer end of Salt Island, parallel to the one above described, 1500 feet long, terminating at a depth of 25 feet at low water; and as it would have been about 1400 feet distant from the other, and was to be provided with a jetty at right angles to its extremity, it would have provided an additional low-water harbour of 40 acres. The estimated cost of this work was 240,000*l.*; and if to this be added the probable outlay on the additional wet dock above mentioned of 124,000*l.*, it will be found that a total low-water space of 46 acres, and an additional tidal space of 25 acres, together with a wet dock of 23 acres, or a total floating area of about 94 acres, with an ample extent of quay accommodation, sufficient for any amount of packet or general commercial business, would have been provided at a comparatively moderate expenditure.

Unhappily Mr. Rennie's plans were not carried out; and though his original design admirably answered the purpose intended, and the whole of the packet service was satisfactorily performed at the old port for many years when an extension of Holyhead Harbour was determined upon, the Government (after Mr. Rennie's death) employed an engineer who proceeded upon an entirely new plan, the execution of which, when completed, will probably cost upwards of two millions sterling; and, after all, when the rocky and bad nature of the holding-ground within it, is taken into account,* its security and convenience are still matters of considerable doubt amongst naval men.

During the period in which he was engaged in carrying out the works at Holyhead, Mr. Rennie was also constructing harbours at Howth and Kingstown, with the same object of facilitating the communication between the ports of England and Ireland. Howth Harbour was opened for packets in 1819, previous to which time they had sailed from the Pigeon House, at the mouth of the Liffey, in Dublin Bay. When the piers at Kingstown Harbour were sufficiently advanced to be available for the service, the packets were removed to that port, the depth of water being greater, and the situation on the whole more convenient.†

Among the other harbour works constructed by Mr.

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* It will be remembered that the 'Great Eastern' was nearly wrecked in consequence of the bad holding-ground within the new harbour in the year 1859.

† Mr Rennie's plan of Kingstown Harbour consisted of two piers of four arms each carried out from the shore 3700 feet distant from each other, their heads inclined inwards at an angle of 122 degrees, and terminating in a depth of 26 feet at low water of spring tides. The width between the outer angles of the two outer arms of the pier was 1150 feet, the entrance pointing N.E. ½ E. The total space enclosed was 250 acres. The works were commenced in 1817, the first stone being laid by the Earl of Whitworth, the Lord Lieutenant; and the works were still in progress at Mr Rennie's death in 1821. The harbour subsequently fell under the jurisdiction of the Irish Board of Works, and all sorts of new plans were adopted at variance with the original design of Mr. Rennie, in carrying out which it is to be feared that the harbour has been seriously injured.

Rennie in England, were the Hull Docks. These were of great importance, and urgently required for the accommodation of the large trade of that rising port. What is called the Humber Dock was begun in 1803 and finished in 1809.* The principal difficulty encountered in the execution of these works was in getting in the foundations of the dock walls—the bottom presenting a great depth of soft mud. They were set on timber piles and platforms well bound together, with truncated arches of stone over them. A powerful steam-engine was employed to draw the water from the coffer-dam in front of the Humber entrance, to enable the foundations of the cill to be got in, and the lock gates (which were of stout oak) to be fixed.

It was in the course of executing the Hull Harbour works that Mr. Rennie invented the dredging-machine, as it is now used, for the purpose of clearing the basins of mud and silt. Various unsuccessful attempts had before been made to contrive an apparatus with this object. A series of rollers, armed with spikes to rake up the deposit, followed by buckets and spoons to lift it from the bottom, worked by means of a walking wheel between two barges, was the most common practice; but it was clumsy, tedious, and inefficient. Other machines for a similar purpose were driven by tread-wheels. At length the idea was taken up of fixing a series of buckets to an endless chain, worked by horse power. Mr. Rennie carefully investigated all that had previously been attempted in this direction, and then proceeded to plan and construct a complete dredging-machine, with improved machinery, to which he yoked the power of the steam-engine. He was thereby enabled to raise as much as 300 tons of mud and gravel in a day from a depth of 22 feet; and the expedient proved completely successful.

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* This dock is 900 feet long by 370 wide. It covers a surface of 7 acres, and is capable of holding about seventy sail of square-rigged vessels. The entrance lock, communicating with the tidal harbour opening into the Humber is 42 feet wide and 158 feet long between the gates, with the cill laid 6 feet below low water of spring tides.

The same kind of machine was extensively used by Mr. Rennie in executing his various harbour works. One of these, constructed for the excavation of the Perry Dock at Blackwall in 1802, was furnished with a powerful apparatus for splintering rocks and large stones, which could not otherwise be removed; and it answered the purpose most effectually. In the Clyde, the Thames the Mersey, and the Witham, as well as in various foreign rivers, the dredging-machine, as contrived by Mr. Rennie, has been found invaluable; and there is scarcely a port or harbour in the United Kingdom in which it has not been most beneficially employed.

In addition to these docks and harbours, Mr. Rennie furnished the plans of the new quays and docks at Greenock on the Clyde in 1802; and those at Leith, the port of Edinburgh, in 1804. Neither of these schemes was carried out to the full extent, chiefly for want of funds; but the improvements effected at the former port were considerable, and at Leith two large docks, 1500 feet long, and two small ones, 750 feet long, constructed along the shore between the old tidal harbour and the village of Newhaven, provided a large amount of additional accommodation for the growing trade of the port.

Mr. Rennie was also consulted in 1805 respecting the improvement of Southampton; and the measures which he recommended in his elaborate and able report, formed the beginning of a series of works of almost national importance. Mr. Rennie's clear-sighted prognostications of the future prosperity of the port – arising from its great natural advantages in respect of security, capability of extension, the excellent anchorage of Southampton Water, the central situation of the place on the south coast, and its moderate distance from London—have been amply fulfilled; its subsequent connection with the capital by railway having given an impulse to its improvement and prosperity far beyond what even his sagacious mind could at that time have foreseen.*

In his harbours, as in all his engineering works, Mr. Rennie proceeded upon certain definite principles, which he arrived at after a careful study of the whole subject. He was averse to all makeshifts and temporary expedients. When he was asked to give his advice as to the *best* means of rendering a harbour efficient, he stated his views fully and conscientiously, holding nothing in reserve. He set forth the whole cost which he believed would be incurred, and no less. He abhorred setting traps in the shape of low estimates, to tempt men to begin undertakings, when he knew that they would be exceeded. He spoke out the whole truth. "You want a harbour," he would [illegible] "of such strength as to be *safe*, with piers able to [illegible] the greatest possible force of the sea. Well, here is [illegible] plan I recommend: it is the best that I can suggest. But I tell you the whole cost which I think will be incurred in its construction. Adopt the plan or not, as you think proper."

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* It would occupy much space to mention in detail the various harbours in the United Kingdom which Mr. Rennie was employed to examine, report upon, and improve; but the following summary may suffice:—In England he examined and reported on Rye Harbour (1801); Dover (1802); Hastings projected Harbour (1806), Berwick, where he constructed the fine pier at the mouth of the Tweed, 2740 feet in length (1807); Margate Harbour (carried out 1808); Liverpool Docks, on which he made an elaborate report (1809); North Sunderland (1809); Shoreham (1810); Newhaven (1810); Harbour of Refuge in the Downs, north of Sandown Castle, on which he made a careful report (1812); Prince's Dock, Liverpool, of which he furnished the designs (1812); Bridlington (1812); Sidmouth (1812); Rye, a second report (1813); Blyth (1814); Ramsey, Isle of Man (1814); Port Leven, Mount's Bay, Cornwall (1814); Bridgewater (1814); Whitehaven (1814); Scarborough (1816); the improvement of the navigation of the river Tyne (1816); Yarmouth (1818); Fishguard, Wales (1819); Kidwelly, Wales (1820); and Sunderland (1821). He also suggested various improvements, many of which were carried out, in the following harbours of Scotland, besides those above mentioned:—Loch Buy, Isle of Skye (1793); Port Mahomack, near Tarbet Ness (1793); Kirkcudbright and Saltcoats (1799); Craigmore, near Boroughstoness (1801); Montrose (1805); Ayr, where the improvements recommended by him were carried out (1805); Peterhead (1806); Frazerburgh, only partially carried out (1806); Charleston (1807); Alloa (1808); St. Andrew's (1808); Portnessock, Galloway (1813); Ardrossan (1811 and 1815); and Portpatrick (1819). In like manner he was consulted, and reported, as to the following Irish harbours:—Westport (1805); Ardinglass (1809); Dublin (1811); Balbriggan (1818); Donaghadee (1819); and Belfast (1821). He was also consulted respecting dry docks at Malta (1815), and a harbour and docks at Bermuda (1815).

He would never consent to reduce the strength of his piers and retaining walls, *under* the limits which he thought essential for their stability. He would not risk his reputation and character upon slop-work; he would rather lose his chance of employment altogether. Hence so many of his large but effective designs for the improvement of our most important harbours remained unexecuted, or have been only carried out to a limited extent; sometimes by engineers who had not mastered the fundamental principles on which his plans were founded, and in such a manner as frequently to lead to vast inconvenience and almost endless expense.

In his report on the Earl of Elgin's proposed harbour at Charleston, on the north shore of the Frith of Forth, in the year 1807, he very clearly laid down the broad principles on which he held that such works should be designed: "Every harbour," he said, "should be [illegible] constructed as to have its mouth as much exposed as possible to the direction from whence vessels can most conveniently enter in stormy weather, when they are least manageable; but the Heads should be made of such a form as [illegible] admit of the least sea entering it, or so as to occasion [illegible] little swell within the haven as possible. This cannot, by any practicable construction, be *entirely* avoided, [illegible] means should be provided within the harbour so as to [illegible] the recoil of the waves to a minimum,—for it is [illegible] undertow or retiring sea, after the breaking of a wave, [illegible] renders vessels most unmanageable by causing the [illegible] its effec[illegible] such a time the mariner is at a loss what to do, or [illegible] manage his vessel, and for the want of due att[illegible] to these particulars, many of the most considerable artificial harbours in the kingdom are exceedingly difficult of access, and some of them are most unsafe even when entered." The great point, he held, was not only to making a harbour to keep out the sea, but to do so in such a manner as to render its entrance from the most exposed or dangerous quarter easy in stormy weather, when its shelter was most needed, and while it must be so designed as to afford a safe shelter for shipping, it must also be safe to enter and safe to get out of.*

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* From the following brief description, it will be observed how skilfully he carried out these views in laying out the intended harbour at Charleston He proposed to construct two great piers, one placed at the western extremity of the little inlet, to which a railway was being laid down—the straight part extending outwards about 154 yards, from which there were to be two kants of about 64 yards each, the last going 57 yards below low-water mark From thence there was to be a return bend about 70 yards long, in a direction considerably to the north of east.* At 50 yards from the extremity of this pier, another of the same length was proposed to be made, forming an angle with it of about 120 degrees, with two other kants similar to the former, and a larger one extending to the shore, the entrance being 50 yards wide, and the outer arm or kant of the east pier making an angle of 120 degrees with it, so that both the outer arms made similar angles with each other A large [illegible] would thus be enclosed, which [illegible], would make a very commodious and capacious harbour "By the above construction," he says in his report, "though it may seem that its exposure will admit of the swells from the south and south-west getting into the harbour, yet when it is considered that the angle at which a wave will strike the Heads will occasion a rebound in a similar angle to that in which it is struck, and as this will be the case from each Head, it follows that these reflected waves, meeting each other, will occasion a resistance which will have the effect of preventing a considerable part of the sea wave from entering the harbour, and what does enter it will expend its fury on the flat beach within and soon become quiet" This might he added, be in a great measure prevented by extending the pier-heads further seaward but which the large additional expense precluded him from recommending and, indeed, there would always be abundant shelter for the shipping under one or other of the pier heads Besides, as the Frith was only about two miles wide at the place, the proba-

That so many modern harbours, constructed at great cost, are found comparatively inaccessible in severe weather, is, we believe, to be accounted for mainly by the circumstance, that they have been laid out after no definite rule or principle whatever. If they succeed, it is the result of a happy accident; and if they fail, it is supposed that the failure could not have been helped. Even within the last twenty years several expensive havens have been constructed, which have proved to be so dangerous that they can scarcely be used. But by Mr. Rennie's forms of piers, vessels, if they have only steerage-way, *must* enter the harbour in safety. They cannot strike on the pier-heads, and, if ordinary care be used, the very recoil of the waves forces them forward into port; and, as any swell which might enter would have ample space to expend itself, the ship could either be brought up, or take the beach without damage if necessary.

Again, a sailing vessel, on leaving the harbour, supposing the wind to be blowing right in, could lie out upon either tack and make an offing, if it were prudent to put to sea at all. And although the narrowed distance between the two pier-heads might be termed the entrance, yet in effect it is not so; for the moment the vessel gets within the outer angles of the two return arms or kants, she may be said to be in or out of the harbour, as the case may be. In this way the fullest width of entrance and the smallest space for the admission of swell are ingeniously and effectually secured.

Whilst occupied on the works of the Ramsgate Harbour, of which he was appointed engineer in 1807, Mr. Rennie made use of the diving-bell in a manner at once novel and ingenious. It will be remembered that Smeaton had

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bility was that there would be no such heavy seas as to render so expensive a measure necessary. The plan was, however, carried out to only a limited extent, and we merely quote the report because of the valuable principles to be observed in the construction of harbours, which are here so clearly enunciated.

employed this machine in the operations connected with the building of the harbour;* but his apparatus being wood, was exceedingly clumsy, and very limited in its uses.' In that state Mr. Rennie found it, when he was employed to carry on the extensive repairs of 1813. The east pier-head was gradually giving way and falling into the sea at its most advanced and important point. No time was to be lost in setting about its repair; but from the peculiarly exposed and difficult nature of the situation, this was no easy matter. The depth at the pier-head was from 10 to 16 feet at low water of spring tides; besides, there was a rise of 15 feet at spring and 10 feet at neap tides, with a strong current of from two to three knots an hour setting past it both on the flood and at the ebb. The work was also frequently exposed to a heavy sea, as well as to the risk of vessels striking against it on entering or leaving the harbour.

Mr. Rennie's first intention was to surround the pier-head by a dam; but the water was too deep and the situation too exposed to admit of this expedient. He then bethought him of employing the diving-bell; but in its then state he found it of very little use. No other mode of action, however, presenting itself, he turned his attention to its improvement as the only means of getting down to the work, the necessity for repairing which had become more urgent than ever. Without loss of time he proceeded to design and construct a bell of cast iron, about 6 feet in height, 4½ feet wide, and 6 feet long, having one end rather thicker and heavier than the other, that it might sink lower, and thus enable the exhausted or breathed air more readily to escape.

At the top of the bell, eight solid bull's-eyes of cast glass were fixed, well secured and made water-tight by means of leathern and copper collars covered with white lead, and firmly secured by copper screw bolts. To the top of the inside were attached two strong chains for the purpose of fastening to them any materials that might be required for the work, and flanges were cast along the sides of the bell, on which two seats were placed, with footboards for the use of the men while working. In the centre of the top was a circular hole, to which a brass-screwed lining was firmly fixed, and into this a brass nozzle was screwed, having a leathern water-tight hose fastened to it, 2½ inches in diameter. The hose was in lengths of about 8 feet, with brass screwed nozzles at each end, so that it could be lengthened or shortened at pleasure, according to the depth of water at which the men in the bell were working.

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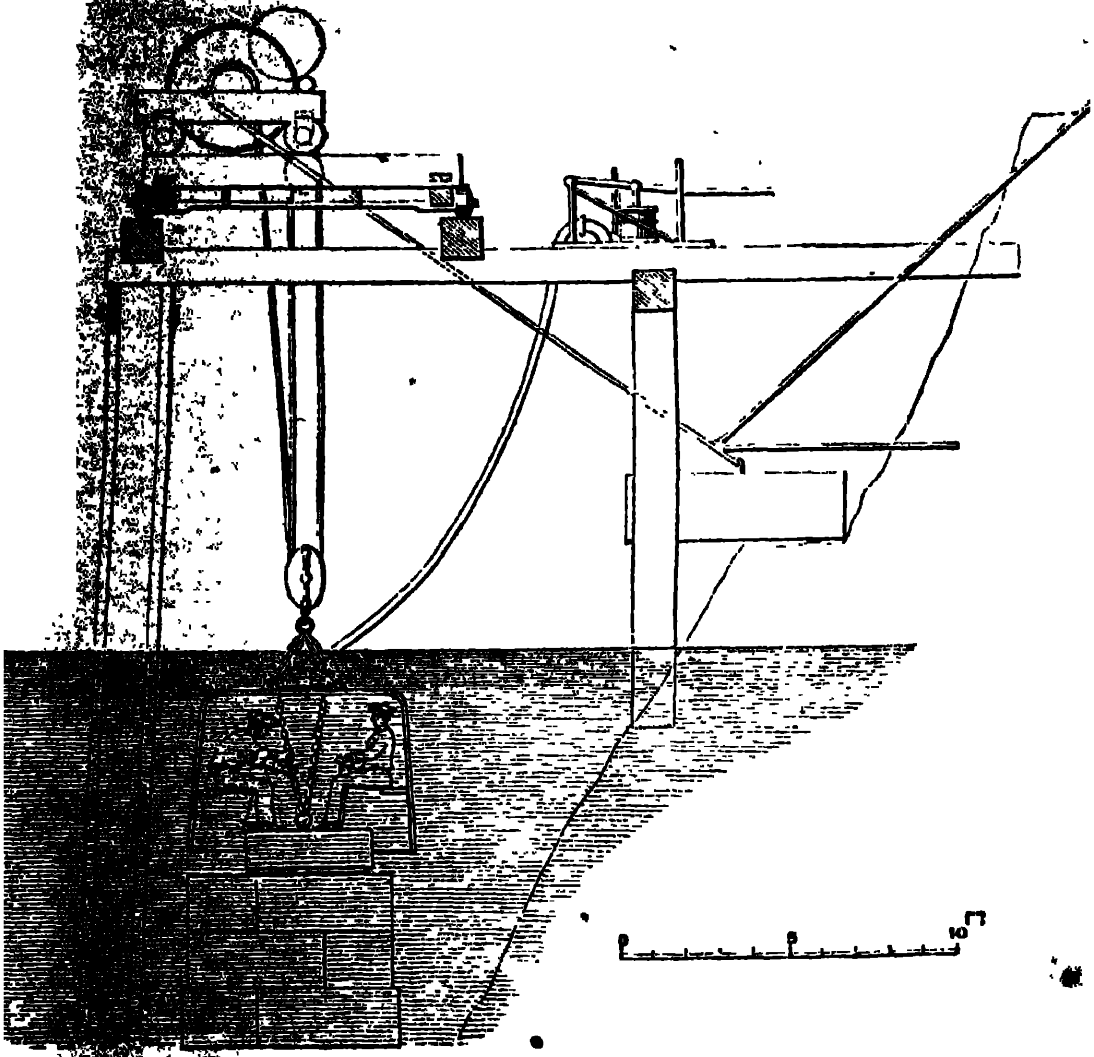
* See Life of Smeaton, p. 159.

For the purpose of duly supplying the machine with air, a double air-pump was provided, which was worked by a sufficient number of men. The air-pump was connected with the hose referred to, and was either placed on the platform above or in a boat which constantly attended the bell while under water. Two stout wrought-iron rings were fixed on the top of the machine, to which ropes or chains were attached for the purpose of lowering or raising it. The whole weighed about five tons; and it was attached to a circular framework of timber, strengthened by iron, erected over where the intended circular pier-head was to be built, and so fixed to a pivot near the centre of the work, that it was enabled easily to traverse its outer limits.

On the top of the framework was a truck, made to move backwards or forwards by means of a rack on the frame, and a corresponding wheel provided with teeth, worked by a handle and pinion. On the truck were placed two powerful double-purchase crabs or windlasses, one for working the diving-bell suspended from it, and the other for lowering stone blocks or other materials required for carrying on the operations at the bottom of the sea. By these ingenious expedients the building apparatus was so contrived as to move all round the new work, backwards and forwards, upwards and downwards, so that every part of the wall could be approached and handled by the workmen, no matter at what depth; while the engineer stationed on the pier-head above could at any time ascertain, without descending, whether the builders were proceeding in the right direction, as well as the precise place at which they were at work.



Method of using the Diving-Bell.

Everything being in readiness for commencing operations, the divers entered the bell and were cautiously lowered to the place at which the building was to proceed. A code of signals was established by which the workmen could indicate, by striking the side of the bell a certain number of strokes with a hammer, whether they wished it to be moved upward, downward, or horizontally; and also to signal for the descent of materials of any kind. By this means they were enabled, with the assistance of the workmen above, to raise and lower, and place in their proper bed, stones of the heaviest description; and by repeating the process from day to day, and from week to week, the work was accomplished with as much exactness, and almost as much expedition, under water, as though it had been carried on above ground.

Thus the entire repairs were completed by the 9th of July, 1814; and to commemorate the ingenuity and skill with which Mr. Rennie had overcome the extraordinary difficulties of the undertaking, the trustees of the harbour caused a memorial stone to be fixed in the centre of the new pier-head, bearing a bronze plate, on which were briefly recorded the facts above referred to, and acknowledging the obligation of the trustees to their engineer. They also presented him at a public entertainment with a handsome piece of plate in commemoration of the successful completion of the work. The diving-bell, as thus improved by Mr. Rennie, has since been extensively employed in similar works; and although detached divers, with apparatus attached to them, are made use of in deep-sea works, the simplicity, economy, and expeditiousness of the plan invented by Mr. Rennie, and afterwards improved by himself, continue to recommend it for adoption in all undertakings of a similar character

CHAPTER IX.

MR. RENNIE'S WAR DOCKS AND OTHER GOVERNMENT WORKS.

FROM an early period Mr. Rennie's eminent practical abilities pointed him out for employment in the public service; and he was consulted by the Ministry of the day more particularly as to the machinery used in the Government establishments, as to the formation of royal docks, and the construction of breakwaters. At the recommendation of Mr. Smeaton he was called upon by the Victualling Department of the Navy to advise them as to the improvement of their flour-mills at Rotherithe, which were worked by the rise and fall of the tide; and the manner in which he performed that service was so satisfactory, that it led to his advice being taken on other subjects, some of which might at first sight be supposed to lie beyond the range of engineering experience.

Great alarm prevailed in 1803 as to the warlike intentions of the French, who threatened to invade England. The 'Moniteur' and the 'Brussels Gazette' were openly speculating as to the time that it would take for the French army to reach London. It therefore behoved England to be upon her guard. All the possible lines of approach from the coast to the capital were carefully examined; and it appeared to military men that the eastern side of London was the most accessible to the advance of an enemy landing near the mouth of the Thames, or on the Essex coast. Mr. Rennie was employed to examine the valley of the Lea, to ascertain whether means could be devised for suddenly laying it under water, if necessary, to check the approach of a hostile army from that quarter. After careful consideration, he laid before the Government a plan with that object, which included a series of dams furnished with sluices,—one at the junction of the Lea with the Thames, another across the valley at Bow, a third at Temple Mills, and others higher up that river, as far as Amwell. These were contrived so that the waters should be penned up, and the valley flooded at will. The works were, however, only partially carried out. Five dams were formed above Bromley, with jetties at different points to increase the current; but happily the defensive works were never required, Napoleon's warlike ambition having shortly after become diverted in another direction.

But again, about 1806, when Napoleon's legions were assembled on the heights above Boulogne, and all his flat-bottomed boats were in readiness to receive them, further steps were taken to defend the south-east coast from the expected invasion. Martello towers were erected along the coast from Folkestone to Beachy Head; and among the other means adopted was the formation of a military canal from Sandgate to Rye, the designing of which was entrusted to Mr. Rennie. In a letter to Mr. Boulton, of Birmingham, dated the 22nd May, 1806, he observes:— "You may possibly remember that from the cliffs west of Sandgate, to a place called Cliffend, about three miles west of Rye, in Sussex, there is an extensive marsh, which lies along the sea-coast, composed of Romney Marsh, Guildford Marsh, the Mead, Winchelsea, and Pet Levels, all of which make about 60,000 acres.* On the interior site of the marshes the country rises suddenly to the height of some 100 to 150 feet. A canal, about thirty miles in extent, is now being constructed, and is indeed nearly finished, round the marsh, and at the foot of the high land. This canal is 60 feet wide and 9 feet deep. It is defended on the land side by a strong rampart with bastions which flank it from end to end. Within the rampart, there is a wide military road on which artillery can be transported with great expedition, under cover of the rampart, from one bastion to another, as may be required. The bridges across this canal are all temporary, and may be broken down on the approach of an enemy."

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* See Descriptive View of Romney Marsh, vol. i. p. [illegible]

Mr. Rennie was also consulted as to the best site for a low-water harbour on the south-east coast, for the purpose of accommodating frigates to watch the opposite shore. His opinion was in favour of Folkestone as the best site for such a port, where a ridge of rocks outside its then small tidal basin offered unusual facilities for the formation of a haven capable of accommodating vessels of considerable burden. This work was not, however, carried out, and Folkestone Harbour is now devoted to more pacific purposes.*

When Fulton proposed the scheme of his famous torpedo for blowing up ships at sea, by stealthily approaching them under water, Earl Stanhope made so much noise about it in the House of Lords, that a commission, of which Mr. Rennie was a member, was appointed to investigate its merits. Little importance was attached to Fulton's pretended "invention;" nevertheless it was determined to afford him an opportunity of exhibiting the powers of his infernal machine, and an old Danish brig, riding in Walmer Roads, was placed at his disposal. He succeeded, after an unresisted attack of two days—during which he had also the assistance of Sir Home Popham—in blowing up the wretched carcass, and with it his own pretensions as an inventor.†

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* Mr. Rennie seems to have been frequently in communication with the military authorities of the day on warlike matters. Thus, in 1809, he was applied to for a gang of workmen to proceed to Flushing, during the unfortunate Walcheren expedition, to assist in destroying the piers, floodgates, and basins of that port; after effecting which they returned home.

† Mr. Rennie had a very mean opinion of Fulton, regarding him as a quack who traded upon the inventions of others. He considered that little merit belonged to him in regard to the invention of the steamboat. Thus, Jonathan Hulls, Miller of Dalswinton, and Symington had been at work upon the invention long before Fulton. Fulton's alleged invention of cast-iron bridges was not more original. Writing to Mr. Barrow of the Admiralty, in 1817, Mr. Rennie says:—"I send you Mr. Fulton's book on Canals, published in 1796, when he was in England, and previous to his application to

Among other subjects on which we find Mr. Rennie consulted by the Government authorities, were the improvement of the machinery of the Waltham Powder Mills, especially as to the more economical application of the water power—the fixing of moorings in the tideways of the royal harbours—the clearing of the Thames in front of Woolwich Dockyard of its immense accumulation of mud—the erection of a quarantine establishment in the Medway*—the provision of wet docks for the Royal Navy

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the steam-engine to the working of wheels in boats. On the designs (as to bridges, &c.) contained in that book, his fame, I believe, principally rests; although he acknowledges that Earl Stanhope had previously proposed similar plans, and that Mr. Reynolds of Coalbrookdale in Shropshire, had actually carried them into execution; so that all the merit he has—if merit it may be called—is a proposal for extending the principle previously applied in this country. The first iron bridge was erected at Coalbrookdale in 1779, and between that and the publication of Fulton's book in 1796 many others were erected; so that, in this department, he has little to boast of. I consider Fulton, with whom I was personally acquainted, a man of very slender abilities, though possessing much self-confidence and consummate impudence."

* The quarantine establishment of the port of London was then situated at Stangate Creek, which joins the Medway about two miles above Sheerness. It consisted of several old two and three-decker hulks, into which goods were placed. Passengers while performing quarantine might well fret and fume at their detention, having before them a most uninteresting prospect—a wide extent of flat marsh-land, with a fringe of mud at low water. A small vessel of war was stationed at the entrance of the creek to prevent infringement of the regulations. The annoyance caused by this establishment was very great, and it was more and more complained of as our foreign commerce extended. On several occasions, vessels filled with passengers, having accidentally run foul of the ships performing quarantine, were compelled at once to heave-to, and undergo two or three days' detention before they could be released. To diminish this evil, the Government determined to erect a permanent quarantine establishment about three miles up Stangate Creek, at a place called Chetney Hill, a small rising ground situated in the marshes. It was proposed to isolate this hill by a canal, provided with a lock; and Mr. Rennie was requested to prepare the requisite plans, which he did (in 1806), and the works were executed at a heavy expense; but we believe they were never used, and the old hulks continued to be employed until the final abandonment of the quarantine system.

—and the introduction of improved machinery at the various dockyards; on which last subject Mr. Rennie was especially competent to give advice.

A Commission of Civil Officers of the Navy was appointed, in 1806, to consider the best means of turning out work from the dockyards with the greatest despatch and economy. Private manufacturing establishments were then a long way ahead of the Government yards, where methods of working, long abandoned everywhere else, still continued in practice; and to call a mechanic or labourer on the Thames "a regular dockyarder" was to apply to him the lowest term of reproach that could be used. Foreign governments were introducing steam-engines and the most improved kinds of machinery, whilst our Admiralty were standing still, notwithstanding the war with France, which called for more than ordinary despatch in the building and repairs of ships of war.

In Mr. Rennie's report to the Commission, he incidentally mentions mechanical appliances which he was engaged at the time in manufacturing for exportation. "I am erecting," he said, "a steam-engine for the royal dockyard at Copenhagen, for the purpose of blowing all the bellows in the smithies, and another for pumping water out of the docks. I also understand they mean to construct machinery there for forging anchor-palms and other large iron work. Rolling-mills for bars, bolts, hoops, &c., might also be employed with advantage. Saw-mills, such as I have constructed at Calicut, on the coast of Malabar, for sawing plank, beams, and other articles, would be very serviceable. Block-machinery and rope-works might likewise be worked by steam-engines, as well as mills for rolling copper, machinery for working cranes, and other purposes."

He pointed out, that dockyards ought to be so laid out as to enable work of the same kind to be carried on by continuous operations, as in a well-ordered manufactory. He showed that the water at the entrance of all the dockyards, excepting Plymouth, was too shallow to enable large ships to be docked for repairs, without dismantling them and taking out their guns and stores, which was a cause of much delay, damage, and expense; and he urged the provision of a dockyard in which the largest ships might lie afloat at low water, and be docked and undocked in all states of the tide. He would also have powerful steam-engines provided, by which any dock might be pumped dry in a few hours, so as to enable repairs to be at once proceeded with. He had no doubt that the cost of constructing such a harbour and dock would be saved to the nation in the course of a very few years. He also urged, as of still greater importance, the necessity for concentrating all dockyard work as much as possible. Himself the head of a large manufacturing establishment, he was well aware that the more the several branches are kept apart from each other, the less is the efficiency secured, and the greater is the waste of material as well as loss of time. He therefore urged above all things concentration, and he broadly held that without it economy was impossible

Portsmouth, Plymouth, Pembroke, Sheerness, Chatham, Woolwich, and Deptford were mostly far apart, some of them very badly adapted for the purposes of royal dockyards, and at nearly all of them the same costly process of patching, cobbling, and waste was going forward. Indeed, he held that it would be much cheaper, viewed as a money question only—not to mention the increased despatch of business and the improved quality of the workmanship—to construct an entirely new dockyard, where every department could be laid out in the most complete and scientific manner. These views looked so reasonable, and they pointed to results so important, that the Board of Naval Revision determined to pursue the investigation; and they requested Mr. Rennie to examine all the royal dockyards, and report as to the improvements that might be made in them with the above object; and also on his plan of a new and complete naval arsenal suitable to the requirements of the nation.

The result of his inquiries was set forth in the elaborate report delivered by him on the 14th May, 1807. He had found most of the royal harbours in a state of decay, silted up with mud or sand, and in a generally discreditable condition. Of all the naval arsenals, he found Plymouth had suffered the least, in consequence of less alluvial matter flowing into the harbour from the rivers discharging themselves into the Sound—the principal objection to that port being that it was exposed to the violence of south-westerly and south-easterly winds. Portsmouth he found to be in a very defective state, much silted up with mud, the depth on the bar having become reduced within a century from 18 to 14 feet, whilst the works generally were in a condition of great decay. The docks were also, in his opinion, quite inadequate to the accommodation of ships requiring repairs, whilst the storehouses, workshops, and building-slips were ill laid out, having been run up in haste after no well-digested plan, involving bad work and waste both of money and of time.*

Deptford Royal Dockyard, the oldest on the Thames, was objectionable because of the decreasing depth of water, which rendered it less and less available for ships of large burden; and hence it was gradually being abandoned for ship-building purposes; Mr. Rennie recommending that it should for the future be exclusively used as a victualling yard. Woolwich also he considered ill adapted for the purposes of a royal harbour and arsenal: it was situated too high up the river, where the water was shallow, and the place was incapable of enlargement to the required extent, except at an enormous cost. He held that large ships, even if built there, must go down the stream into deeper water before they could take in their guns, stores, and provisions, thus involving the risk of damage and the certainty of delay and increased expense.

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* By way of illustrating his views, Mr. Rennie used to say—"Let any stranger visit Portsmouth Dockyard, the head establishment of the British Navy, he will be astonished at the vastness and number of buildings, and perhaps say, 'What a wonderful place this is!' knowing nothing about the subject. But I can compare the place to nothing else than to a pack of cards, with the names of different buildings, docks, &c., marked upon them, and then tossed up into the air, so that each, in falling, might find its place by chance,—so completely are they devoid of all arrangement and order."

With reference to the naval arsenals on the Medway, although considerable improvements had been made in the dry and wet docks at Chatham, yet he held that the place was from its situation, incapable of being adapted to the important purposes of a naval establishment, of such extent and accommodation as should be commensurate with the national requirements. Besides, the navigation of the Medway from the Nore was very intricate, and the upper part too shallow for ships of large burden.

Then, as for Sheerness, his opinion was that the yard there, besides being on too small a scale to adapt it for the purposes of a national harbour and arsenal, would be exposed to great risk in event of a war, being almost incapable of effectual defence. "On the whole," he observed, "it appears to me, on consideration of all the facts I have been able to collect respecting the principal naval arsenals of the empire, that they are far from possessing such properties, either in point of situation, extent, arrangement, or depth of water in the harbours, as the large and growing naval power of this country demands."

In reviewing the sites of the different arsenals, Mr. Rennie says he was struck with surprise to find them mostly placed on the *lee shore* of their respective harbours—the worst of all positions. Plymouth, Portsmouth, Chatham, and Sheerness were thus situated; Deptford was on the weather shore, and Woolwich had the prevailing wind blowing across it. He also pointed out that, at all the royal dockyards, vessels had to take in their stores and be rigged and fitted out in the open harbours; and, with the exception of Plymouth, the materials were clumsily and expensively conveyed from the shore to the ship's side in lighters. There being *no wet docks* at any of the royal yards, vessels in ordinary lay moored out in the open tideway; and the expense of moving them, of placing men on board to watch them, and the various accidents to which they were thus liable, were the constant cause of heavy loss to the nation.

Regarding the subject in all its bearings, and with a view to despatch, efficiency, and economy, Mr. Rennie strongly recommended the construction of capacious wet and dry docks, in some convenient situation on a weather shore, provided with sufficient storehouses and workshops, fitted with engines and machinery on the most improved plans for the building and repair of ships; and he expressed his strong opinion that the political importance of adopting such a measure would far outweigh the expense, however large, which it might be necessary to incur.

The subject was felt by the Admiralty authorities to be of so much importance, that Mr. Rennie was again requested to report as to the most advisable site for a great naval harbour and arsenal such as he had proposed; and he was requested by Lord Howick (then First Lord) more particularly to state his views as to the eligibility of Northfleet on the Thames, which had been suggested as the most desirable situation. In his visit of inspection to the place, Mr. Rennie was accompanied by his venerable friend James Watt, and his confidential assistant Mr. Southern, together with Mr. Whidbey, acting master-attendant at Woolwich Dockyard; and he had the benefit of their great experience in maturing the design which he shortly after laid before the Admiralty for their consideration.

The proposed site seemed to him most convenient for the purpose of a great naval harbour and arsenal. "Northfleet," he said, "possesses every advantage that can possibly be wished for in a naval station, and it is capable of being rendered as complete and perfect an establishment as can be made for building, repairing, and fitting out vessels of war of all classes, on the largest scale." The Thames at that point presented abundant depth of water; there was a large space of flat land available for the harbour and docks, which might be so laid out as to be almost indefinitely extended; the situation was on the weather shore, well protected, and capable of being strongly defended; it would be in direct connection by water with Woolwich, Deptford, and London, as well as with Chatham and Sheerness; and as a great national harbour and arsenal, he regarded its situation on the Thames, at the entrance to the greatest port in the world, as in all respects the most suitable and appropriate. Accompanying his report was a carefully devised and most elaborate plan,* which unhappily was never carried out.

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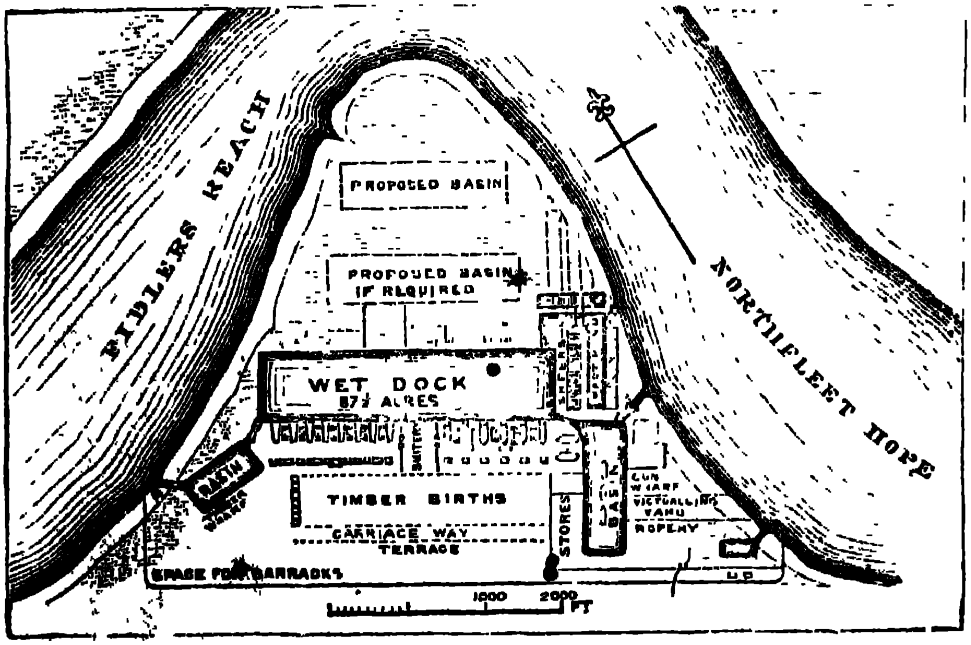
* The site of the proposed arsenal was the flat portion of land near Northfleet, about eight hundred acres in extent, lying in the angular space formed by Fidlers' and Northfleet Reaches. Its depth close to the shore was about seven fathoms at low water, or sufficient for vessels of the largest burden. The main entrance-lock was to be at the Northfleet end of the docks, within which was to be an entrance-basin 1815 feet long and 600 feet wide, covering about twenty-five acres. Dry docks were to be placed conveniently near, from which the water was to be pumped by powerful steam-engines, so that vessels might be docked directly from the basin, and have their bottoms examined with the least loss of time. Part of the entrance-basin was to be appropriated for an anchor-wharf, another for a gun-wharf; next the stores and victualling wharves, with their appropriate buildings; the whole arranged on a system, so that the materials required on shipboard might be passed forward to their respective wharves from one stage of preparation to another, with the greatest despatch and economy. At the north end of the basin were to be the mast and boat ponds, with their adjoining workshops, connected also with the Thames and the main western basin by separate entrances. The main western basin was to be at right angles to the entrance-basin, 4000 feet long and 950 feet wide, covering a surface of about eighty acres. Alongside were to be six dry docks and eight building slips, all fitted in the most complete manner with the requisite saw-pits, seasoning-sheds, mould-lofts, timber stores, and smitheries, conveniently situated in the rear. The whole of the heavy work, such as bellows-blowing, tilt-hammering, forging of anchors, and iron-rolling, was

Mr. Rennie was also consulted respecting the improvement of the old royal dockyards, and submitted various plans

to be performed by the aid of steam-engines and machinery of the most perfect kind. Seventy sail of the line, with a proportionate number of smaller vessels, might conveniently lie in this basin, and yet afford abundant space for the launching of new vessels. Another basin, 980 feet long and 500 feet wide, was proposed for timber-ships, on the south-west extremity of the great basin, with a separate entrance into the Thames a little below Greenhithe. The whole of the arsenal was to be connected together by a system of railways extending to every part and all round the wharves. The plan was most complete, some of the details being highly ingenious. But the cost of executing the work was the real difficulty; Mr. Rennie's estimate of the total outlay requisite to complete the works amounting to four millions and-a-half sterling. Yet the plan was so masterly and comprehensive, and so obviously the right thing to be done, that the Portland Administration determined to carry it out, and the necessary land was bought for the purpose. Frequent changes of Ministry, however, took place at the time; the resources of the country were heavily taxed in carrying on the war against Napoleon in Spain; the public attention was diverted in other quarters; and no further steps were taken to carry out Mr. Rennie's design. He knocked at the door of one Administration after another without effect. In 1810 we find him writing to Lord Mulgrave, the First Lord; to the Right Hon. George Rose to the Earl St. Vincent, and others



Proposed Docks at Northfleet.

with this object, the most important of which were only carried out after the Northfleet project had been finally abandoned. Of the new works executed after our engineer's designs those at Sheerness were the most extensive. The royal dockyard there was felt to be a public disgrace. It consisted of a number of old wooden docks and basins, formed by ships' timbers roughly knocked together from time to time, as necessity required. The ground, in its original state, had been merely an accumulation of mud and bog, surrounded by a wide extent of flat wet land.

It is easy to conceive how, in ancient times, Sheerness must have been regarded as of importance, occupying as it does the extreme north-western point of the Isle of Sheppey, and commanding the entrance both of the Thames and the Medway. But, with the improvements in modern artillery, the place has in a great measure

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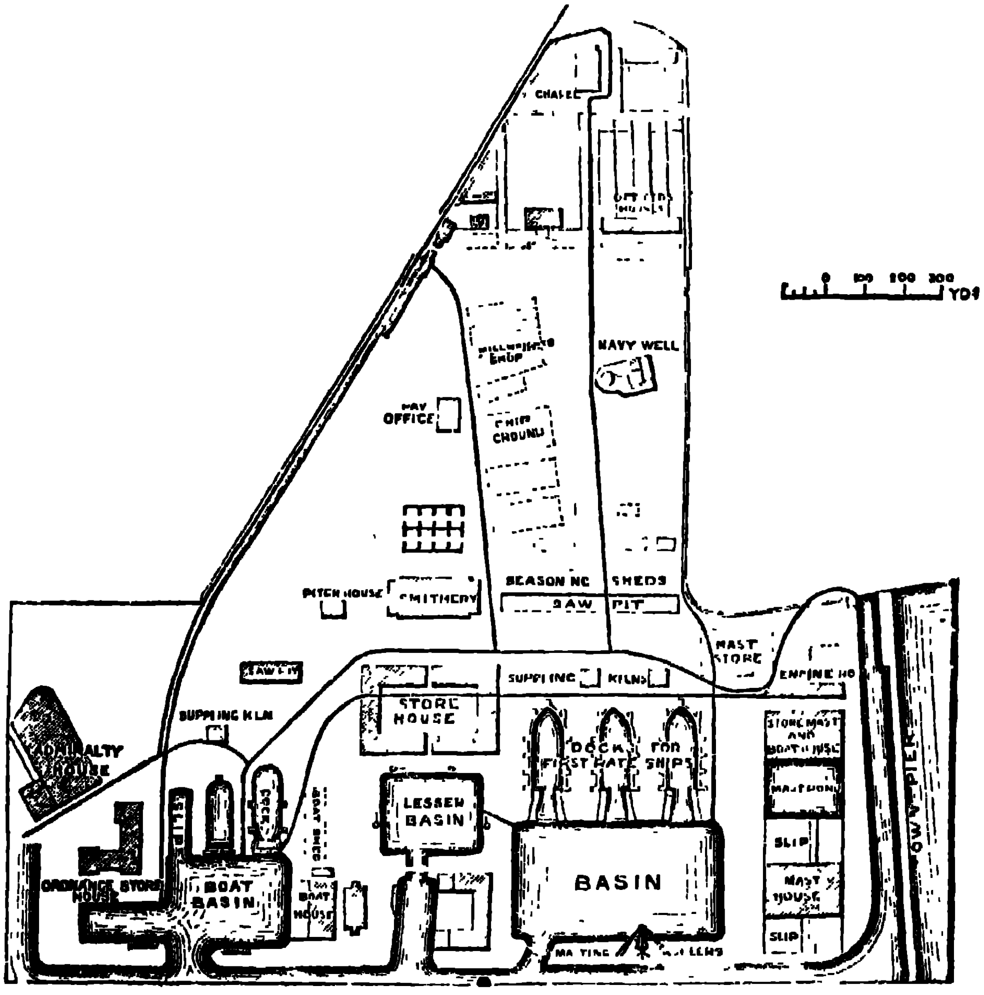
but though the more the plans ere scrutinised, the more indisputable did their merits appear, he could find no Ministry strong nough to carry them out. When eace came, Government and peole were alike sick of wars, naval rmaments, and glorious victories; nd believing that all danger om France was at an end,—the rench fleet having been destroyed r captured, and Napoleon banished to St. Helena,—it was supposed that the old royal harbours, patched and cobbled up, might answer every purpose. So the land at Northfleet was sold, and the whole subject dismissed from the public mind. But, after the lapse of half a century, the wisdom of Mr. Rennie's advice has become more clearly apparent even than before. For years past, the waste in our dockyards, which it was the chief object of his Northfleet design to prevent, has become one of the principal topics of public discussion, and it has been the standing opprobrium of every successive Naval Administration. What Mr. Rennie urged fifty years since still holds as true as ever—that *without concentration economy is impossible.* So long as Government goes on tinkering at the old dockyards, spending enormous sums of money in the vain attempt to render them severally efficient, and maintaining separate expensive staffs in so many different places,—building a ship in one yard and sending it round the island to another, perhaps more than a hundred miles distant, to be finished and fitted, and then to another to take in its guns, stores, &c.,—so long shall we have increasing reason to complain of the frightful waste of public money in the royal dockyards.

ceased to be of value as a public arsenal, being incapable of efficient defence against a hostile fleet. Mr. Rennie entertained a strong opinion as to the inferiority of the site compared with others which he pointed out; but from the time when he was directed to prepare plans for the reconstruction of the dockyards, his business was confined to carrying out his instructions in the best possible manner.



Sheerness Docks.

The plan finally decided upon was that of a river-front, extending from the Garrison Point to near the Old Town Pier of Sheerness, of the length of 3150 feet, including the entrances, and enclosing within it three basins: one to the north, 480 feet long and from 90 to 200 feet wide, containing a surface of about two acres, 4 feet below low water of spring tides, with two frigate-docks and a building-slip and boat-slips; a central tidal basin 220 feet square, of the depth of 2 feet below low water, with storehouses around it for the reception and delivery of victualling and other stores; and on the west end of the dockyard a basin 520 feet long and 300 feet wide, covering a surface of nearly four acres, provided with dry docks for ships of the line on the south side, with their sills and the bottom of the basin laid 9 feet below low water of spring tides, westward of which were the mast-ponds, mast-locks, and workshops. In the rear, on the south of these works, were placed sawpits, timber-berths, and the officers' houses. The total surface of the dockyard was 64¾ acres. The foundation-stone of the docks was laid by the late Lord Viscount Melville in 1815, and the works were commenced and continued without interruption until the year 1826, when the whole were completed.

Their execution was attended with many difficulties, and necessarily required a great deal of Mr. Rennie's care and attention. The foundations were a soft running sand, extending to an almost fathomless depth. The strong currents flowing past the place rendered it necessary to adopt an entirely new system of operations, which were carried out to an extent never before attempted in so exposed a situation. That form of sea-wall was devised which should most effectually resist the strong pressure of the current, and the heavy swell beating upon its outer side, without yielding to the lateral pressure or thrust of the water of the basins and the earth by which it was backed. At the same time the weight necessary to ensure stability must not be such as to sink vertically. Mr. Rennie adopted the means to secure these objects which he had employed with such success at Grimsby Docks in 1797, namely, to take the like quantity of materials as would have been necessary for an ordinary wall, and dispose of them in such a form, that the same weight should be distributed over a greater surface, thus diminishing the vertical pressure.

In the foundations of the walls he also adopted the method employed by him in similar works, of driving the piles and cutting off their heads at an angle inclining inwards, or towards the land side, laying the courses of stone at the same angle; by which a greater resistance was offered to the pressure of the earth, and the building was prevented from being pushed outwards, as was more or less the case in most of the walls built on the old construction. The entrance gates to the great basin were also planned and executed with great skill, Mr. Rennie carrying into effect the same simple but correct principles laid down by him in his report on the Northfleet docks, making the direction of the entrance suitable to the current in the river Medway, and from which the ships entered the port.

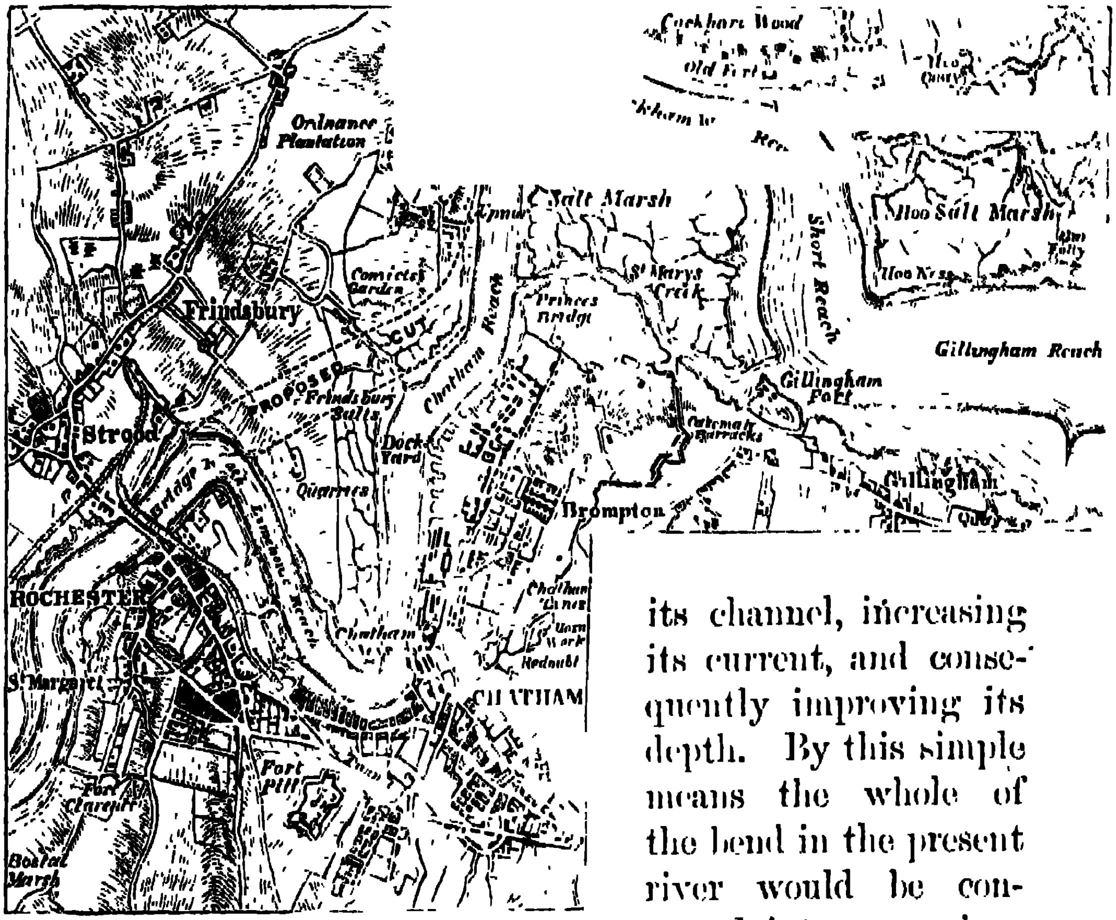
The coffer-dams in which these Cyclopean walls were built demand a passing notice because of their gigantic dimensions and the great depth at which they were founded, at not less than from 27 to 28 feet below low water of spring tides. They were composed of four rows of piles about 12 to 14 inches square. The two centre rows were carried about 4 feet above the level of high water of the highest spring tides, and were driven from 20 to 30 feet into the sea-bottom. The outer and inner rows were about 7 feet from the two centre main rows, but only extended up to the level of the half tide, and were driven from 15 to 20 feet into the ground. All the piles were hooped and shod with wrought iron, firmly bound together at the bottom, middle, and top, with timber braces and wrought-iron bolts and ties in every direction. The joints were caulked with oakum and covered with pitch, and the spaces between the piles were filled with well-tempered clay, so that they were as nearly water-tight as possible, notwithstanding the tremendous weight of the sea outside at the top of each tide. Though the dams somewhat changed form by this pressure and inclined inwards, the piles were prevented being forced in that direction by powerful counteracting braces, and the whole stood fast until the completion of the work, contrary to the expectations of many, who regarded it as an altogether impracticable thing to construct coffer-dams of such magnitude in so exposed a situation, where the pressure to be resisted was so enormous.

The only accident which occurred to the coffer-dams was in 1820, when the old 'Bellerophon' line of battle ship, which had been anchored outside to break the swell, was forced from her moorings by a fierce storm from the north-east, and driven against the piling, a large extent of which gave way, and the waters rushed in upon the works. Fortunately, the building of the wall was by this time considerably advanced, so that no great damage was done. On the fall of the tide the dams were repaired without difficulty, and the works proceeded to completion.

Among Mr. Rennie's other dock works may be mentioned the new river-wall, with a ship-basin and two building-slips, at Woolwich; the new dockyard, building-slips, and dry dock at Pembroke; the new entrance to Deptford Basin; and various improvements at Chatham, Portsmouth, and Plymouth.

One of Mr. Rennie's most ingenious plans was that proposed by him for the improvement of Chatham Dockyard. He saw large sums of money expended from year to year in the ineffectual patching-up of the old yards, with little good result; and he foresaw that eventually the Government, if it would secure efficiency and avoid waste, must fall back upon some such plan as his Northfleet Docks to obtain the requisite economy by concentration of dockyard work. In 1818 he was requested to report on the best means of improving Chatham Dockyard, when he again pointed out the great loss to the nation by maintaining so many separate yards, all of which were being tinkered and mended at an enormous cost.

He then boldly recommended that the Government should sell Deptford Dockyard, which he held to be comparatively useless, and devote the proceeds to the improvement of Chatham, after the plan which he submitted. It consisted in cutting a new channel from a point in the river Medway, a little below Rochester Bridge, to another point lower down the river at Upnor Castle, thus straightening its channel, increasing its current, and consequently improving its depth. By this simple means the whole of the bend in the present river would be converted into a capacious wet dock, extending along the whole front of the dockyard, and shut in by gates at either end. He also proposed to make another cut from its lower end to join the Medway at Gillingham, where there is ample depth of water at all times for ships of the largest burden.



Plan of Medway Improvement.

Lord Melville was much struck with the simplicity and at the same time the comprehensive character of the plan, and wished to have an estimate of the cost. The whole amount—including land, labour, and materials—according to the engineer, would not exceed 685,000*l.*, against which there was to be set the heavy annual cost for moorings in the tide-way (which would be saved) or equal to a capital sum of 200,000*l.*; the expense of watching vessels lying at moorings, amounting to about 15,000*l.* a year, or equal to a capital sum of 300,000*l.*; and the amount realised by the sale of the disused dockyard at Deptford, which of itself would have been almost sufficient to defray the entire cost of this magnificent new arsenal,—not to mention the saving in the steam and other vessels employed in carrying stores to the men-of-war lying in ordinary along the course of the Medway, and the great despatch and economy which would have been secured in all the operations connected with the building, fitting, and repairs of ships.

The plan, however, was too comprehensive, and was not adopted. Building and patching are still going on at Chatham, at a cost far exceeding that required to carry out Mr. Rennie's design; but it still remains to be seen whether anything like the same amount of concentration and efficiency will be secured.

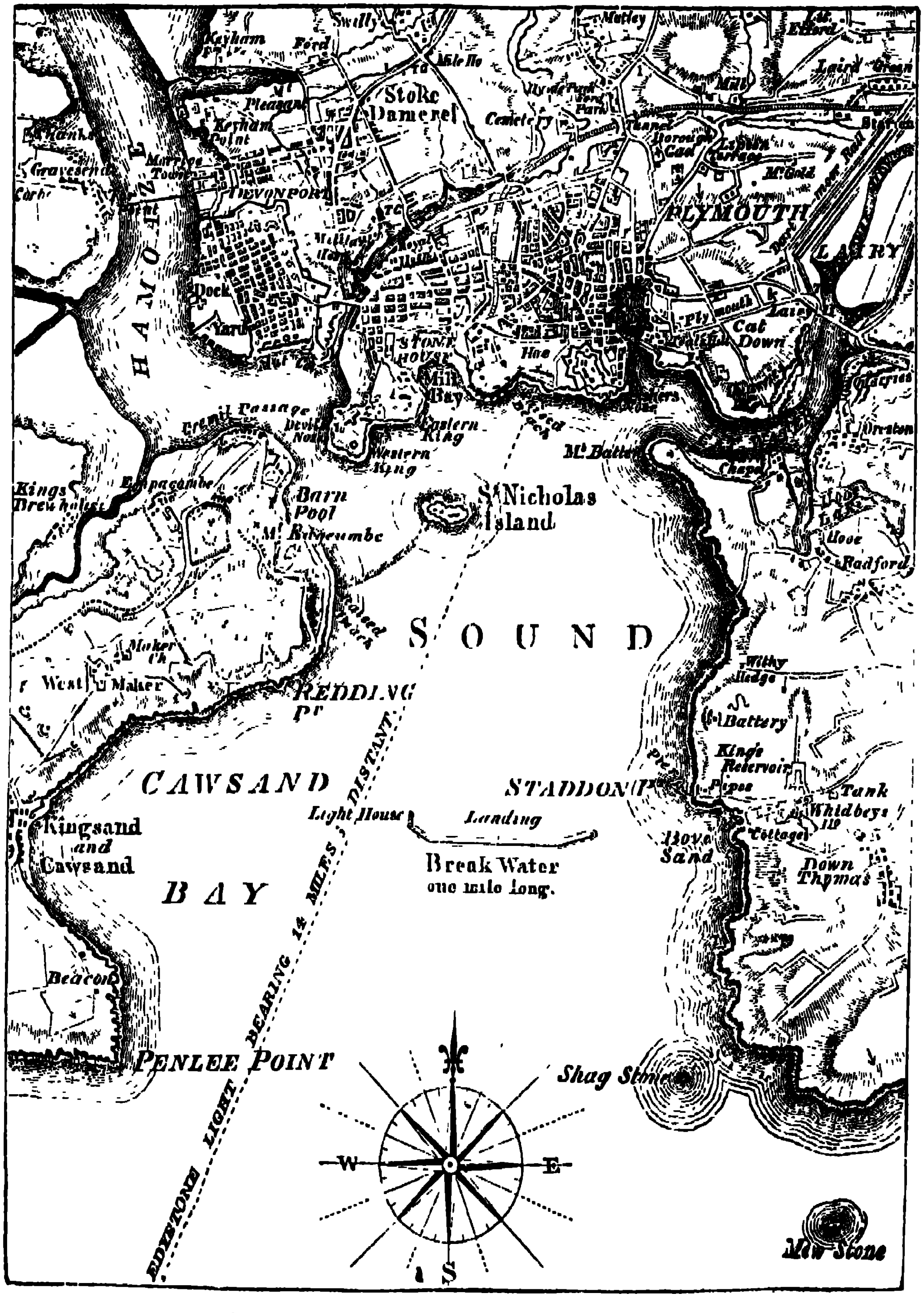
CHAPTER X.

PLYMOUTH BREAKWATER.

THE harbour of Plymouth being situated at the entrance to the English Channel, nearly opposite two of the principal French coast arsenals, has always been regarded as a naval station of national importance. The great area of the Sound, its depth of water, and its connection with the two spacious and secure inner harbours of Hamoaze and Catwater, admirably fit it for such a purpose. The Sound is more than three miles wide in all directions, and includes an area of about four thousand acres, with a depth of water varying from four to twenty fathoms at low water of spring tides. Its shores are bold and picturesque, rising in some places in almost perpendicular cliffs; in others, as at Mount Edgcumbe, the land, clothed with the richest verdure, slopes gently down to the water line.

The only natural defect of the haven—and it was felt to be a serious one—was that the Sound lay open to the south, and was consequently exposed to the fury of the gales blowing from that quarter during the equinoxes. The advantages presented by its excellent anchorage and great depth of water were thus in a considerable degree neutralized, and the cases were not unfrequent of large vessels being forced from their moorings during storms, and driven on shore.

From an early period, therefore, the better protection of the outer harbour of Plymouth was deemed to be a matter of much importance, and various plans were proposed with that object. One of these was, to carry out a pier from near Penlee Point, at the south-western entrance to the Sound, for a distance of above 3000 feet, into deep water; another was, to construct a pier several thousand feet long,



Map of Plymouth Sound. [Ordnance Survey.]

from Staddon Point to the Panther rock; and a third contemplated a still more extensive pier, of above 8000 feet in length, extending westward into deep water, from the south-eastern entrance to the Sound. While the question was under discussion, the Lords of the Admiralty called upon Mr. Rennie to report upon these several plans, and to advise them what, in his opinion, was the best course to be pursued. In his preliminary inquiry, which was of the most thorough kind, he was assisted by Mr. Joseph Whidbey and Mr. James Hemmans.

Mr. Whidbey had been a sailing master in the Royal Navy, and was a most able and meritorious officer. He had sailed round the world with Vancouver, and raised himself from the station of a man before the mast to the highest position a non-commissioned officer could reach. His varied experience had produced rich fruits in a mind naturally robust and vigorous. As might be expected, he was an excellent seaman. He was also a person of considerable acquaintance with practical science, and had acquired from experience a large knowledge of human nature, of a kind that is not to be derived from books. He was afterwards raised to the office of Master-Attendant at Woolwich Dockyard, and was greatly beloved and respected by all who knew him. Mr. Hemmans was Master-Attendant of Plymouth Dockyard, and possessed an intimate practical knowledge of the locality, which proved of much value in the course of the investigation.

The result of Mr. Rennie's careful study of the object to be accomplished, and the best mode of fulfilling the requirements of the Admiralty, was embodied in the report presented by him on the 22nd of April, 1806. He there expressed himself of opinion that, of the three plans which had been proposed, that of a pier extending westward from Andurn Point, near the Shagstone, at the south-eastern extremity of the Sound, was the best; but even that was objectionable, as calculated to produce shoaling of the harbour by favouring the deposit of silt—a process which was then going on, and which it was most desirable to prevent. Looking at the main object of the proposed work, which was to render the Sound a safe haven for vessels riding at anchor there, as well as to increase the security of Plymouth inner harbour, he considered that another method might be adopted, with greater certainty of success, at much less cost, and without any risk of silting up the entrance of the harbour.

It may here be explained that, in its original state, there were three channels of entrance into the Sound: one on the west side, 3000 feet wide, between the Scottish Ground rocks and the Knapp and Panther rocks; another, on the eastern side, 1800 feet wide, between the shore and the Tinker, St. Carlos, and Shovel rocks; and a third in mid channel, also about 1800 feet wide, which was rarely used, being through dangerous rocks on either side. Any works which might be constructed across this middle channel, it appeared to Mr. Rennie, would be of no detriment to the navigation of the Sound. On the other hand, by narrowing the passage through which the tidal waters flowed in and out, the tendency would be to increase the scour, and consequently to deepen the two remaining channels—an object only second in importance to the protection of the harbour itself.

His plan accordingly was, to form a Breakwater across the middle channel by throwing into the sea large angular blocks of rubble, of from two to twelve tons each, leaving them to find their own base, and to continue this process until a sufficient mass had been raised to the level of half-tide, so as to make a ridge, about 70 yards broad at the base and 10 yards at the top, these dimensions to be afterwards varied and increased according to circumstances. He proposed that the Breakwater should be of a total length of 5100 feet; of which 3000 feet, forming the central part, was to be in a straight line across the Sound, and 1050 feet at either end inclined inwards at an angle of 160 degrees. It was also proposed to run out a pier of

2400 feet, in two arms, from Andurn Point, at the south-eastern entrance to the Sound, but this part of the design was not carried into effect. The total estimate of cost, including the Point Andurn pier, was 1,102,440*l.*

View of the Breakwater from Mount Edgcumbe. [By Percival Skelton, after his original Drawing.]

The formation of breakwaters by a similar process had been practised from an early period; and by such means the moles of Venice, Genoa, Rochelle, Cherbourg, and other ports, had been formed. Mr. Rennie had himself adopted the same method in forming the harbours of Howth, Kingstown, and Holyhead; and the success which had followed his operations at those places left no doubt in his mind as to the practicability of constructing an efficient breakwater across Plymouth Sound, though the situation was admitted to be much more difficult. Mr. Rennie considered that a ridge of rough, heavy stones would be the simplest and least costly, as it would probably be found the most efficient, plan of protection that could be devised. By throwing in the blocks in the given line, and allowing the waves by their own action to form the slope or angle of repose at which the materials would lie, the expenditure of an infinity of labour and money would be avoided. In this kind of work he held that success was to be secured by following the laws of nature; and, with reference to the proper slope, his own expression was that "the waves were the best workmen."

The report in which Mr. Rennie embodied these recommendations excited great interest amongst naval men, and led to much discussion. Many pronounced the scheme to be visionary and impracticable. It was also alleged that, even if it could be executed, such a work would prove altogether useless. Others held that it would destroy the Sound for purposes of navigation, and lead to its complete silting up; whilst a greater number criticised and condemned it in all its details. Amongst other critics, one of the most severe was the late General Sir Samuel Bentham, a brother of Jeremy the philosopher, who strongly recommended a plan of his own, consisting of one hundred and forty wooden towers, with stones sunk between them in a double line. Five years' controversy thus passed, and numerous designs were prepared, submitted, and considered, all of which were referred to Mr. Rennie, who still remained as firmly satisfied as ever of the expediency of his design, and vindicated its superiority over all others which had been proposed. At length the Lords of the Admiralty were won over to his views, as well as Earl St. Vincent, Lord Keith, and many other leading naval officers. Lord Melville was then at the head of the Admiralty, and when he had become fully persuaded as to the merits of Mr. Rennie's plan, and ascertained that there was a growing unanimity of opinion in its favour, he exerted himself strenuously to have it carried into effect.

The result was, that an Order of Council was issued on the 22nd June, 1811, by which the requisite powers were given to proceed with the works. Mr. Rennie was appointed engineer in chief, and Mr. Whidbey resident engineer, with Mr. William Stewart as assistant. It was very difficult to find contractors willing to undertake the execution of a work of so novel and extensive a character, except at prices which the engineer could not sanction; and it was therefore determined only to contract for the labour of the several operations in detail, so that there might be an opportunity for revising the scale of prices from time to time,[*]—the Government undertaking to find the requisite plant and materials.

A piece of ground was purchased from the Duke of Bedford at Oreston, up the Catwater, containing twenty-five acres of limestone, well adapted for the purposes of the work; and steps were taken to open out the quarry, to lay down railways to the wharves, to erect cranes, to build vessels suitable for conveyance of the stone, and to provide the various appliances required for carrying out the undertaking.

On the 12th of August, 1811, the birthday of the Prince

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[*] The propriety of this arrangement was proved by the fact, that whereas the price paid in 1812 for taking and depositing rubble in the Breakwater was 2s. 9d. per ton, it was afterwards reduced to 1s. per ton, as the contractors and workmen became better acquainted with the nature of the work.

Regent, the first stone of the main ridge was deposited on the Shovelbank rock, nearly in the centre of the work. Lord Keith, commander of the Channel Fleet, was present, attended by the chief naval, military, and civil authorities of the port, together with the staff and men of the building establishment.

From this time forward the operations were carried on with despatch when the weather would permit. The workmen began at the centre and worked towards the extremities. The lines of the Breakwater were carefully marked out by buoys, to which the barges laden with the stone blocks were attached whilst they were being emptied into the sea; after which they returned to the quarry wharves, about five miles distant, for fresh cargoes.

For nearly two years this process of emptying in the rubble proceeded; until, in March 1813, portions of the work began to be visible at low water, and by the end of July there appeared a continuous line of about 720 yards. By the month of March in the following year the ridge had been so raised, that its effect in tranquillizing the waters of the Sound during violent south-westerly gales was very considerable, and vessels of all classes sought its protection and came to anchor behind it with perfect confidence.

The Admiral's ship on the station, the 'Queen Charlotte,' of 120 guns, had been heretofore accustomed to ride in Cawsand Bay; but it was now brought to an anchor under the lee of the Breakwater. Among other vessels which took shelter there in 1814 was a large French three-decker, which rode out a severe gale in safety. The year after, when Napoleon entered Plymouth Sound on board the 'Bellerophon,' he expressed himself as greatly surprised with the magnitude of the work, and spoke with admiration of the intentions with which it had been designed and executed.

By the 11th of August 1815, not less than 615,057 tons of stone had been deposited, and a length of 1100 yard. was raised above low water of spring tides. The complet success of the work was now beyond dispute, and exceeded the most sanguine anticipations. Even the most sceptical became convinced of its great practical utility, and many who had before offered vehement opposition to its being begun, became clamorous for its completion on even a larger scale than Mr. Rennie had originally intended.

It was at length determined by the Admiralty, after advising with the engineer, to carry the whole Breakwater twenty feet, instead of ten feet, above the level of low water of spring tides. While the original plan of Mr. Rennie was calculated to afford complete security to the larger class of vessels, this addition to the height doubtless gave more adequate protection to the smaller craft. The finishing of the work above the low-water line, however, involved a more expensive kind of workmanship; for the greatest force of the waves is exercised between the lines of high and low water.

Hence it became necessary to render this upper part of the Breakwater so strong as to present the greatest possible amount of resistance. Mr. Rennie suggested the propriety of increasing the seaward slope to about 5 to 1, so as to give greater strength, and present an increased resistance to the force of the waves. But this recommendation was overruled for the time, and the work proceeded.

The operations were continued without intermission, the stone blocks being deposited at the rate of 1030 tons a-day during the year 1816—a greater average than has since been accomplished in carrying out any similar work, notwithstanding the improved modern appliances of stages provided with steam power, and railways worked by powerful locomotives.* Towards the end of the year, about 300 yards, of the west end of the Breakwater had been raised to the full height of two feet above high water, and 20 feet above low water of spring tides.

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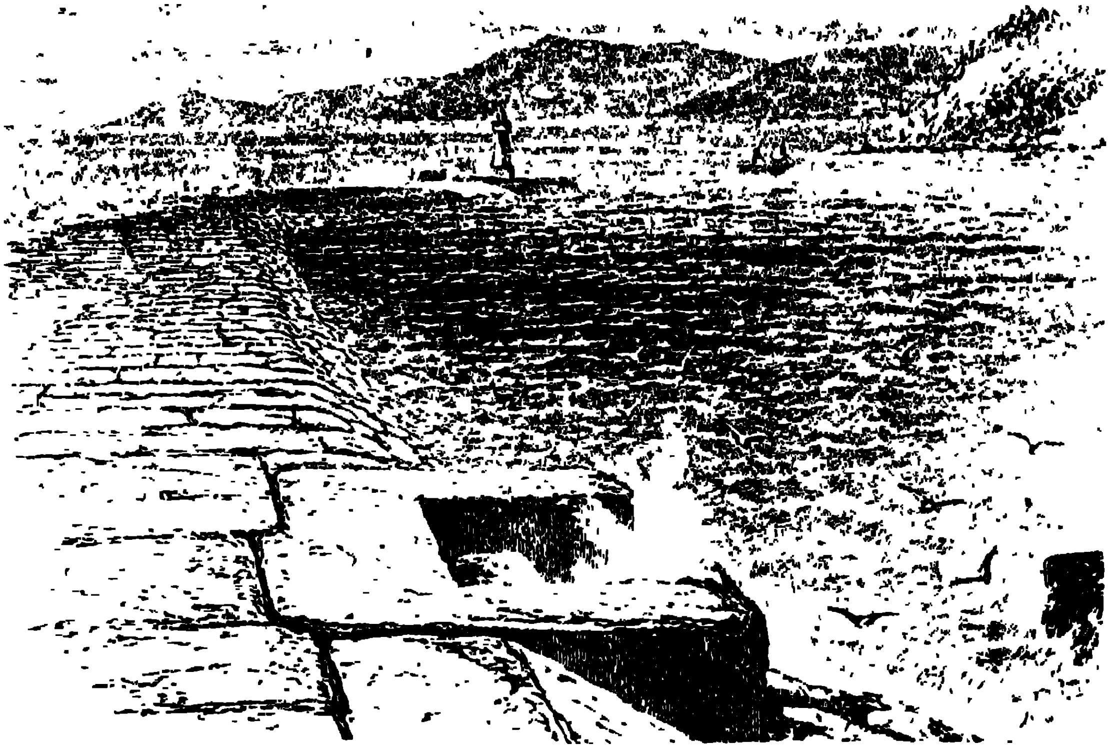
* The largest quantity of stone deposited in one year was in 1821, when not less than 373,773 tons were quarried, lightered, and emptied into the work.

Success, as usual, produced over-confidence; and the authorities on the spot, believing that if the sea slope of the rubble were roughly put together at an inclination of 3 to 1, it would present sufficient resistance, as well reduce the expense, directed it to be so executed. But about this time a succession of severe gales set in from the south-west and sent a tremendous sea upon the Breakwater,—especially one of great violence, which occurred on the 17th of January, 1817.

On examining the work, after the return of moderate weather, it was ascertained that a length of about 200 yards of the rubble of the upper part had been displaced or deranged—that several blocks of stone, varying from two to five tons, had by the force of the waves been thrown over from the south or sea slope to the north or land slope—and that their further effect had been to increase the inclination of the former to 5⅓ to 1, instead of 3 to 1, as it had originally stood.

Nevertheless, the great mass of the Breakwater remained unmoved, and large numbers of vessels, availing themselves of the secure protection which it provided, had been enabled to ride out the storm in safety. Unfortunately, however, the 'Jasper' sloop of war and the 'Telegraph' schooner, anchored without the line of protection, were driven on shore and wrecked under the citadel, when a melancholy loss of life took place.

Mr. Rennie was of opinion that this storm had proved of great service by forcing the stones together and consolidating the work more firmly. His recommendation as to the necessity of increasing the seaward slope having been so singularly confirmed by the action of the waves, he now advised that it should be allowed to remain as left by the storm of the 17th, and that the rest of that face of the Breakwater should be made uniform with it. It would, however, appear that Mr. Whidbey, the resident engineer, contrived to finish most of the exterior face at a slope of only 3 to 1, as before; and thus it stood without any material interruption until several years after Mr. Rennie's death. By that time nearly the whole of the intended rubble, amounting to 2,381,321 tons, had been deposited, and the main arm, with 200 yards of the west arm, making 1241 yards in length, had been raised to the required level.



Plymouth Breakwater. [By Percival Skelton, after his original Drawing.]

The work had arrived at that stage when it had to experience the full force of another terrific storm, which took place on the 23rd of November, 1824. It blew at first from the south-south-east, and then veered round to the south-west; and the effect of this concurrence of winds was to heap together the waters of the Channel between Bolt Head and Lizard Point, and drive them with terrible force into the narrow inlet of Plymouth Sound. This storm was not only greatly more violent, but of much longer duration, than that of 1817. When the Breakwater could be examined, it was found that, out of the 1241 yards of the upper part which had been completed with a slope of 3 to 1, 796 yards had been altered as in the previous storm, and the immense blocks of stone which formed the sea-face of the work had by the force of the waves been rolled over to the landward side, thus reducing the sea-slope, as before, to about 5 to 1.

The accuracy of Mr. Rennie's view as to the proper slope —which was indicated by the action of the sea itself—was thus a second time confirmed; and the same view having been taken by the engineers * who were called upon to make an inspection of the work, and to report as to the best means of rendering it permanently secure,—it was determined to make the permanent slope of the same inclination, and the works were so carried out accordingly.†

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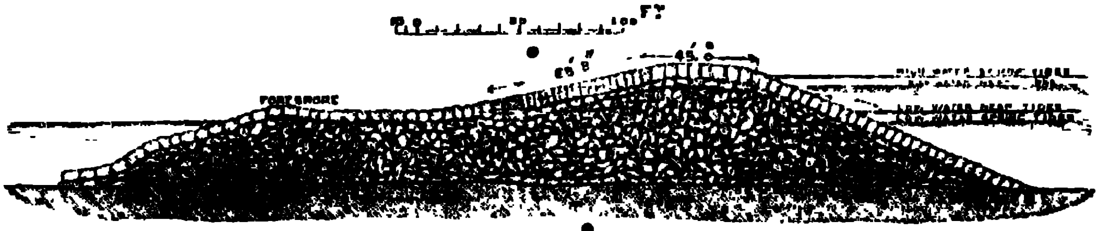
* These were Mr. Telford, Mr. Josias Jessop, Sir J. Rennie, and Mr. G. Rennie. For more full particulars as to the history and construction of the Breakwater, we refer the reader to Sir John Rennie's elaborate work entitled 'An Historical, Practical, and Theoretical Account of the Breakwater in Plymouth Sound.' London, 1818.

† The slopes were paved with blocks of the largest stone, firmly wedged together; the centre line was removed 36 feet further seawards; the top width was reduced 5 feet; a strong binding course of dovetailed granite masonry was built at the bottom of the sea slope, which was laid one foot convex from the bottom to the top; whilst the land slope was laid with close-fitting rubble at the inclination of 2 to 1. It was, however, found, in the course of the work, that the rough paving of the rubble alone was scarcely strong enough to withstand the violence of the waves without a certain degree of yielding; and Sir J. Rennie, having been consulted by the Admiralty, recommended that, in addition to the granite basement binding course, there should be another similar course both in the centre and at the top of the sea slope; and that the remainder should be paved with rough-dressed limestone ashlar, set in courses at right angles to the slope, about three feet deep on the average — each course binding well with the one adjacent,—the lower parts of the granite bonding courses being laid level, but the upper parts forming part of the slope. It was still found that there was a difficulty in preventing the outer edge or base of the sea slope, where the main lower granite bonding courses were placed, from being undermined by the waves; and it was determined to place a trench-

The total quantity of rubble deposited to the end of 1848—when the work may be said to have been completed—was 3,670,444 tons, besides 22,149 cubic yards of masonry, or an amount of material at least equal to that contained in the Great Pyramid. The whole cost of this magnificent work was about a million and a half sterling, including a convenient and spacious watering place at Bovesand Bay.

As forming a convenient and secure haven of refuge for merchant ships passing up and down Channel, along the great highway between England, America, and India—as well as a capacious harbour for vessels of war, wherein fifty ships of the line, besides frigates and smaller vessels, can at all times find safe anchorage—Plymouth Breakwater may in every respect be regarded as a magnificent work, worthy of a great maritime nation.

ing or foreshore on the outside of the sea slope, 40 feet wide in the centre of the Breakwater, increasing to 50 feet wide at the commencement of the western arm, and diminishing towards the eastern arm to the width of only 30 feet. This foreshore was about 2 feet above the level of low water of spring tides next to the toe or base; and the surface was roughly paved with rubble well wedged together. The whole of the slope was paved with well-dressed courses of ashlar masonry without mortar, 3 feet 6 inches deep, well bedded down upon the rubble below. The extremity of the western arm was furnished with a solid head of circular masonry, 75 feet diameter at the top, with slopes of 5 to 1 all round. At the point at which the lighthouse has since been placed, an inverted arch of solid blocks was formed, the whole well-bonded, dovetailed, and dowelled together, and firmly united with the other parts of the solid rock. These works answered admirably, and Plymouth Breakwater now rests as firm as a rock upon the bottom of the sea.



Section of the Breakwater as finished.

CHAPTER XI.

MR. RENNIE'S LAST WORKS—HIS DEATH AND CHARACTER.

In undertakings such as these, of great magnitude and importance, Mr. Rennie was engaged until the close of his useful and laborious life. There was scarcely a project of any large public work on which he was not consulted; sometimes furnishing the plans, and at other times revising the designs which were submitted to him. Numerous works of minor importance also occupied much of his attention, as is shown by the extent of his correspondence and the number of his reports, which contain an almost complete repository of engineering practice.

While he was engaged in designing and superintending the construction of his great London Bridges, the formation of Plymouth Breakwater, the building of the docks at Sheerness, the cutting of the Crinan Canal, and the drainage of the Fens by the completion of the Eau Brink Cut, he was at the same time consulted as to many important schemes for the supply of large towns with water. His report on the distribution of the water supplied by the York Buildings Company in the Strand, in which he proposed for the first time to appropriate a distinct service to the several quarters of the district supplied, was a masterpiece in its way; and the principles he then laid down have been generally followed by subsequent engineers. He also reported on the improved water-supply of Manchester, Edinburgh, Bristol, Leeds, Doncaster, Greenwich and Deptford, and many other large towns in England and Scotland, as well as in the colonies and in foreign countries.*

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* In 1817, his fame having gone abroad as the most skilled water engineer of the day, Captain Dufour of Geneva, came to Eng-

In addition to the various mills and manufactories fitted up by him with new and improved machinery, we may mention that he advised the Bank of England on the subject of the more rapid manufacture of bank-notes by the employment of the steam-engine; and that he entirely re-arranged the Government machinery at Waltham for the manufacture of gunpowder. He erected the anchor-forge at Woolwich Dockyard considered to be the most splendid piece of machinery in its day; he supplied Baron Nagel (then Dutch minister in this country) with designs of dredging-engines for clearing the mud out of the rivers and canals of Holland, and constructed the principal part of the celebrated machinery for making ropes, according to Captain Huddart's patent.

Captain Joseph Huddart, F.R.S., was a man of sound judgment, great nautical experience, and excellent skill as a mechanic and engineer. He was often consulted by Mr. Rennie in reference to marine works of more than ordinary importance. His origin was humble, like that of so many of our early engineers; and, like them also, he was attracted to the pursuit by the force of his genius, rather than by the peculiar direction of his education. He was born at Allonby, in Cumberland, in 1740, the son of a small farmer and shoemaker. From his mother he inherited a strong spirit and a vigorous constitution, combined with sound moral principles, which he nobly illustrated in his life.

Huddart received an ordinary share of education at the common school of his village, to which he added a knowledge of mathematics and astronomy, obtained from the

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land for the purpose of consulting him as to the extension and improvement of the waterworks of that city. Captain Dufour was introduced to Mr. Rennie by the mutual friend of both, the eminent Dr Wollaston. Mr. Rennie made a careful and detailed report on the surveys and plans submitted to him, especially on the engine and pumping machinery of the proposed works; and his advice was followed, very much to the advantage of the citizens of Geneva.

son of his teacher, who had studied those branches of science at Glasgow University. He seems to have been an indefatigable learner, for he also acquired some knowledge of music from an itinerant music-teacher, whose execution he very shortly excelled. His mechanical tastes early displayed themselves. Watching some millwrights employed in constructing a flour-mill, he copied the machinery in a model which he finished just as they had completed their mill. He also made a model of a 74-gun ship, after the drawings given in Mungo Murray's 'Treatise on Navigation and Shipbuilding.'

Captain Joseph Huddart, F.R.S.

At an early age, Huddart was employed in herding his father's cows on a hill-side overlooking the Solway Frith, and commanding a view of the coast of Scotland. There he took his books, with a desk of his own making, and, while not forgetting the cattle, he occupied himself in reading, drawing, and mathematical studies. When a little older, his father set him on the cobbler's stool, and taught him shoemaking,—though the boy's strong inclination was to be a sailor. Large shoals of herrings having made their appearance about this time in the Solway Frith, a small fishing company was started by the Allonby people, in which his father had a share, and young Huddart was sent out with the boats, very much to his delight. He now began to study navigation, carrying on shoemaking in the winter, and herring-fishing at the time when the shoals were on the coast. On the death of his father, he succeeded to his share in the fishery, and took the command of a sloop employed in carrying the herrings to Ireland for sale. During his voyages he applied himself to chart-making, and his chart of St. George's Channel, which he afterwards published, is still one of the best.

The herrings having left the frith, Huddart got the command of a brig, his excellent character securing him the post; and he made a successful voyage to North America and back. His progress was steady and certain. A few years later we find him in command of an East Indiaman. After many successful voyages, in which he happily brought all his ships to port, and never met with any serious disaster, he retired from the service; having been in command of ships of greater or less burden for a period of twenty-five years. He now published many of his charts, the results of the observations he had made during his numerous voyages.

His eminent character, not less than his known scientific knowledge, secured his introduction to the Trinity House as an Elder Brother, and to the direction of the London and East India Docks, in which situations he was eminently useful. The lighting of the coast proceeded chiefly under his direction, and many new lighthouses were erected, and floating-lights placed at various points at his recommendation. Among others, he superintended the construction of the lighthouse at Hurst Point. He also surveyed the harbours of Whitehaven, Boston, Hull, Swansea, St. Agnes, Leith, Holyhead, Woolwich Dockyard, and Sheerness; several of these in conjunction with his friend

Mr. Rennie, who was always glad to have the benefit of his excellent judgment. He made many improvements in ship-building; but the invention for which the nation is principally indebted to him is his celebrated rope-making machinery, by which every part of a cable is made to bear an equal strain, greatly to the improvement of its strength and wearing qualities. This machinery, constructed for him by Mr. Rennie at Limehouse, was among the most perfect things of the kind ever put together.*

In his capacity of advising engineer to the Admiralty, Mr. Rennie embraced every opportunity which his position afforded him of recommending the employment of steam power in the Royal Navy. His advice met with the usual reception from the inert official mind: first indifference; next passive resistance; then active opposition when he pressed the matter further. Naval officers, who had grown old in sailing tactics, could ill brook the idea of navigating ships of war by means of a mechanical invention. Skill in seamanship, of which the old salts were so proud, would be entirely superseded. The navy had done well enough heretofore without steam; why introduce it now? It was a smoky innovation, and if permitted, would only render ships liable to the risk of being blown up by boiler explosions.

Lord Melville, however, listened to Mr. Rennie's suggestions, and at length consented to the employment of a small steam-vessel as a tug for a ship of war, by way of experiment. Mr. Rennie then hired the Margate steamboat, the 'Eclipse,' to tow the 'Hastings,' 74, from Woolwich to two miles below Gravesend, against a rising tide. The experiment was made on the 4th of June, 1819, and proved so successful that the Admiralty were induced to authorise a steamboat to be specially buil' at Woolwich for similar service. This vessel was named the 'Comet;' it was built after the designs and under the direction of the late Mr. Oliver Lang, assisted to a considerable extent by Mr. Rennie, who attended more particularly to the designing and fitting of the engines, which were made by Boulton and Watt. The 'Comet,' though a small vessel, was the parent of other royal ships of vastly greater dimensions. She was only 120 feet long between the perpendiculars, and 22 feet 6 inches in extreme breadth; the draught of water was about 6½ feet, and the power of her engines about 40 horses.

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* Captain Huddart died at his house in Highbury Terrace, London, in 1816, closing a life of unblemished integrity in the seventy-fifth year of his age.

The Admiralty had great doubts as to the width of the paddle-boxes; but Mr. Rennie encouraged them to make the experiment after his design. "Steam-vessels," he observed, "are as yet only in their infancy, and can scarcely be expected to have arrived at anything approaching perfection. Much, however, will be learnt by experience; but unless some risk is run in the early application of the new power, no improvements are likely to be made."* The 'Comet' proved a most efficient vessel the best that had up to that time been constructed. She fully answered the purpose for which she was intended; and the result was so satisfactory, that vessels of increased size and power were from time to time built, until the prejudice amongst naval men against the employment of steam power having been got over, it was at length generally introduced in the Royal Navy.†

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[*] Letter to the Admiralty, 22nd May 1820.

[†] Mr Rennie was engaged for many years in urging the introduction of steam power in the Royal Navy. In 1817 we find him writing to Lord Melville, Sir J. Yorke, Sir D. Milne, and others on the subject. It would appear that Lord Melville had declared that he was determined to employ steam-vessels as tugs, so soon as he could convince the Sea Lords of their advantages; on which Mr Rennie compliments Sir D Milne, saying that he is "glad to find that there is one admiral in the navy favourable to steam-boats." In July 1818, he laments that he cannot convince Sir G Hope or Mr. Secretary Yorke of their utility, but that he is persuaded their adoption *must* come at last On the 30th May, 1820,

The last of Mr. Rennie's great designs was that of New London Bridge, which, however, he did not live to complete. The old bridge had been gradually falling into decay, and was felt to be an increasing obstacle to the navigation of the river. The starlings which protected the piers had of late years been seriously battered by the passing of hoys, barges, and lighters, on which they had inflicted equal injury in return; for vessels were constantly foundering on them, and many were sunk and their cargoes damaged or destroyed.

Emptying stones into the river, to protect the decayed pile-work, had only had the effect of further obstructing the navigation, the scour of the current having formed two great banks of stone across the bed of the river: one about 100 feet below the bridge, and the other about the same distance above it, with two deep hollows between them and the piers, from 25 to 33 feet deep at low water.

The piers and arches were also becoming decrepit. Though the top-hamper of houses had long been removed, and the piers patched and strengthened at various times, the bridge was every year becoming less and less adapted for accommodating the increasing traffic to and from the City. At last it was regarded as a standing nuisance, and generally condemned as a disgrace to the capital. To maintain the structure, inefficient and unsafe though it was, cost the City not less, on an average, than 3500*l.* a year, and this expense was likely to increase very fast.

The Corporation felt that they could no longer avoid

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he writes James Watt, of Birmingham, informing him that the Admiralty had at last decided upon having a steamboat, notwithstanding the strong resistance of the Navy Board. "My reasons," he says, "I understand were satisfactory; but unless the Admiralty cram it down the throats of the Navy Board, nothing will be done; for of all the ignorant, obstinate, and stupid boards under the Crown, the Navy Board is the worst. I am so disgusted with them that, could I at the present moment with decency relinquish the works under them which I have in hand, I would do so at dealing decisively with the subject. They then resolved to take the opinion of the best engineers and architects; and Mr. Daw, the architect of the Corporation, Mr. Chapman, the engineer, and Messrs. Alexander and Montague, two eminent City architects, were consulted as to the best steps to be taken under the circumstances. The result of their deliberations was a recommendation to the Corporation to remove eight of the arches and to substitute four larger ones, as well as to make extensive repairs in the remaining arches, piers, and superstructure.

This plan was referred to Mr. Rennie, Mr. Chapman, and Messrs. Montague, for further consideration. In accordance with Mr. Rennie's custom before making any report, he proceeded at once to master the whole of the facts. He could not otherwise give an opinion that could be relied on. He had the tides and currents watched and noted; he had the river carefully sounded, above and below bridge, from Teddington Lock to the Hermitage entrance of the London Docks. He examined the piers down to their foundations, and explored the bottom of the river, making borings at various points between the one shore and the other.

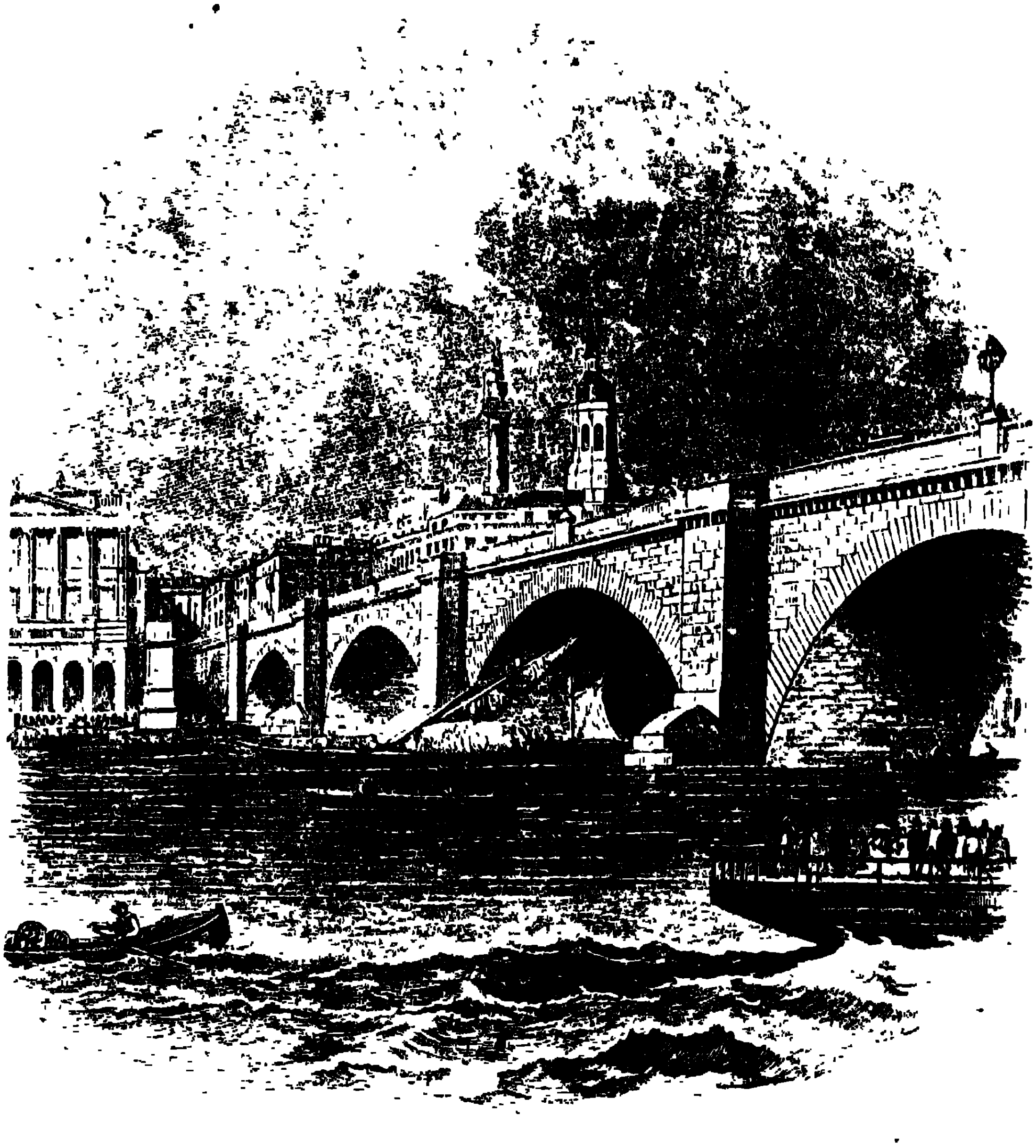
In the report which he made to the Corporation on the 12th of March, 1821, a great deal of new and accurate information was first brought to light respecting the flow of the tide through the arches, and the additional depth of water likely to be secured by their removal. Although it was pronounced quite practicable to carry out the alterations which had been recommended, by erecting four new arches in lieu of the eight old ones, he was of opinion that the cost would be very considerable; and, after all, the old foundations would still present great defects, which could never be wholly cured. Mr. Rennie therefore suggested the propriety of building an entirely new bridge of five arches, with a lineal waterway of not less than 690 feet, in lieu of the then waterway of 231 feet below the top level of the starlings, and 524 feet above them.

Besides the greatly increased accommodation, which would be provided by a new bridge, for the large traffic passing between London and Southwark, Mr. Rennie held that not the least advantage which it promised was the much greater facility which it would afford for the navigation of the river to and from the wharves above bridge; for coasters and even colliers, by striking their masts, might then be enabled to navigate the whole extent of the City westwards. The increased waterway would also enable the waters descending from the interior to flow more readily away, floods often inflicting great damage along the upper shore, especially in the winter months, when the arches of the old bridge had become choked up with ice.

The report was felt to be almost conclusive on the subject; and the more it was discussed the deeper grew the conviction in the minds of all concerned, that its recommendations ought to be adopted. The Corporation accordingly applied to Parliament, in the year 1821, for an Act enabling them to purchase the waterworks under the arches of the old bridge, and to erect an entirely new structure. The bill, of course, had its opponents; some arguing that there was no necessity for a new bridge, and that its erection would be only a useless waste of money, whilst the old one could be repaired and made fit for traffic at so much less outlay.

The case in favour of the new bridge was, however, too strong to be resisted, and Mr. Rennie's evidence was considered so clear and conclusive that committees of both Houses unanimously approved the bill, and it duly received the sanction of Parliament.* Power was conferred by the Act, enabling the Treasury to advance from the Consolidated Fund such sums as might be necessary to supply any deficiency in the funds at the disposal of the Corporation applicable to the erection of the bridge; the Government regarding the work as one of national importance, and consequently entitled to national assistance.

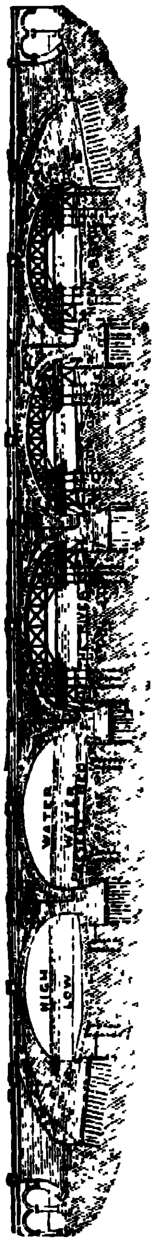
During the progress of the bill through Parliament, Mr. Rennie prepared the general outlines of a design for the new structure. It consisted of five semi-elliptical arches, the centre one 150 feet span, the two side arches



New London Bridge [By Percival Skelton.]

140 feet, and the two land arches 130 feet, making a total lineal waterway of 690 feet; the height of the soffit or under-side of the centre arch being 29 feet 6 inches above

the level of Trinity high-water mark. The general principle of this design was approved and embodied in the bill. Very shortly after the Act had passed, Mr. Rennie was seized by the illness which carried him off, and it was accordingly left to others to execute the great work which he had thus planned.



Section of New London Bridge.

The Corporation of London then appealed to the whole engineering and architectural world for competitive designs, and at least thirty were prepared in answer to their call. These were submitted to a Committee of the House of Commons in the year 1823, and after long consideration the plan originally proposed by Mr. Rennie was finally adopted; on which the Corporation of London selected his son, the present Sir John Rennie, as engineer in chief, to carry it into effect; and the nomination having been approved by the Lords of the Treasury, in conformity with the provision of the Act, steps were forthwith taken to proceed with the work.

It is scarcely necessary to say how admirably Mr. Rennie's noble design has been executed. New London Bridge, in severe simplicity and unadorned elegance of design—in massive solidity, strength, and perfection of workmanship in all its parts—not less than as regards the capacious size of its arches and the breadth and width of its roadway and approaches—is perhaps the finest work of its kind in the world.*

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* The new bridge was erected about thirty yards higher up the river than the old one, and involved the construction of new approaches on both sides. The first coffer-dam was put in on the

It will be observed from the preceding chapters, that Mr. Rennie's life was one of constant employment, and that, apart from his great engineering works, his career contains but few elements of biographic interest. Indeed his works constitute his biography, occupying, as they did, almost his entire life, and nearly the whole of his time. His personal wants were few; his habits regular; and his pleasures of the most moderate sort,—consisting chiefly in reading and in the enjoyment of domestic life. At the age of twenty-nine he married Miss Mackintosh, an Inverness lady. She made his home happy; and he became the father of nine children, six of whom survived him. In the early part of his career in London he lived in the Great Surrey Road, from which he afterwards removed to Stamford Street, not far from his works.

His close and often unremitting application early began to tell upon his health. In 1812, when arrived at the age of fifty-one, he was occasionally laid up by illness. While occupied one day in inspecting the works of Waterloo

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Southwark side, and the first pile was driven on the 15th of March, 1824; the foundation stone was laid with great ceremony by H.R.H. the Duke of York, on the 15th of June, 1825, assisted by the Lord Mayor (Garrett), the Aldermen, and Common Council. The bridge was finally completed and formally opened by His Majesty King William the Fourth, on the 1st of August, 1831—the time occupied in its construction having been seven years and three months. The total cost of the bridge and approaches was about two millions sterling. All the masonry below low water is composed of hard sand-stone grit, from Bramley Fall, near Leeds; and the whole of the exterior masonry above low water is of the finest hard gray granite, from Aberdeen, Devonshire, and Cornwall. The actual width of the arches as executed is as follows: the centre arch is 152 feet 6 inches span; the two arches next the centre are 140 feet; and the two land arches 130 feet. The details of construction of the coffer-dams, piers, and floating and fixing the centres, were similar to those adopted by Mr. Rennie in building Waterloo and Southwark bridges. The total length of the bridge is 1005 feet; width from outside to outside, 56 feet; width of the footpaths, 18 feet; and of the carriage-way, 35 feet. The total quantity of stone built into the bridge is 120,000 tons. The builders were Messrs. Joliffe and Banks, the greatest contractors of their day.

Bridge, he accidentally set his foot upon a loose plank, which tilted up, and he fell into the water, but happily escaped with only a damaged knee. Though unable for some time to stir abroad, he seized the opportunity of proceeding with the preparation of numerous reports, and of working up a long lee-way of correspondence.

In the following year he was frequently confined to the house by a supposed liver-complaint; but his correspondence never flagged. He tried the effects of change of air at Cheltenham; but he had no time for repose, and after the lapse of only a week he was again in harness, giving evidence before a Committee of the House of Commons on Lough Erne drainage. He made another hurried visit to Cheltenham, but evidently took no rest; his absence from active business only affording him an opportunity for writing numerous letters to influential persons at the Admiralty on the subject of his grand scheme of the Northfleet Docks. To one of his correspondents we find him saying he was "better, though only half a man yet." In course of time, however, he partially recovered, and was forthwith immersed in business—engaged upon his docks, bridges, and breakwaters.

He very rarely "took play." In 1815 his venerable friend James Watt, of Birmingham, urged him to pay a visit with him to Paris, shortly after the battle of Waterloo. But Mr. Rennie was too full of work at the time to accept the invitation, and the visit was postponed until the following year, when he was accompanied by James Watt, jun., then of Aston Hall, near Birmingham. This journey was the first relaxation he had taken for a period of thirty years; yet it was not a mere holiday trip, but partly one of business, for it was his object to inspect with his own eyes the great dock and harbour works executed by Napoleon during the Continental war, of which he had heard so much; and to gather from his inspection such experience as might be of use to him in the improvement of the English dockyards on which he was then engaged.

The two set out in September 1816, passing by Dover to Calais and thence to Dunkirk, where Mr. Rennie carefully examined the jetties, arsenal, docks, and building-slips at that port. From thence they proceeded to Ostend, and afterwards to Antwerp, where our engineer admired the great skill and judgment with which the dock works there, still incomplete, had been laid out. From Antwerp they went to Paris, where they stayed only two days, and then to L'Orient and Brest, accompanied by Mr. Joliffe, the contractor. At both these ports, Mr. Rennie took careful notes of the depths, dimensions, and arrangements of the harbours in detail,—receiving every attention from the authorities.

At Cherbourg, in like manner, he examined the building-yards and docks, as well as the progress made with the famous Digue*—a rival to his own Breakwater at Plymouth. At Cherbourg he was joined by Mr. Whidbey, who had come over in a vessel of war to meet him. Mr. Rennie returned to England after less than a month's tour; and though he had made a labour of his pleasure-trip, the change of air and scene did him good, and he entered with zest upon the business of clearing off the formidable arrears of work which had accumulated during his absence. We may add, as an illustration of his habit of turning everything, even his pleasure, to account, that one of the first things he did on his return home was to make an elaborate report to Lord Melville, then First Lord of the Admiralty, of the results of his investigations of the foreign harbours which he had visited in the course of his journey.

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* The Digue is of considerably greater extent than the breakwater at Plymouth, being above 2¼ English miles long. Up to the time of Mr. Rennie's visit, the work had been a series of attempts and failures, which, however, eventually produced experience, and led to success. Wooden cones filled with small stones were first tried; they were sunk so as to form a sea rampart; but the cones were shattered to pieces by the force of the waves, and the stones were scattered about in the bottom of the sea. Then loose rubble-stones were tried; but the blocks were too small, and these, too, were driven asunder. Larger blocks were then used; but, for a time, the smaller stones beneath acted as rollers to the larger ones. At length, however, these found their bearing, and when Mr. Rennie visited the place, the slope formed by the sea-ridge of rubble was as much as 11 to 1. This greatly increased the contents of the breakwater, while its stability was not much to be depended on. Many accidents occurred to the work, and several extensive breaches were made through it by the force of the sea. At low water the height of the Digue was at some parts only three feet; at others, considerably more; whereas, in some places, the top of the work was from seven to eight feet below low water of spring tides. At length, after many years' labour and vast expense, the work has been brought to completion; and it now forms a very excellent defence for the fine war roadstead and arsenal of Cherbourg, greatly exceeding the humble dimensions which it presented when Mr. Rennie visited the place. The whole cost of the works amounted to upwards of seven millions sterling.

After a few years' more devoted application, his health again began to give way. When consulted by Mr. Foljambe of Wakefield, in June 1820, respecting a railway proposed to be laid down in that neighbourhood, he excused himself from entering upon the business, because he was so full of work and his health was so delicate. Shortly after we find him writing to a friend that the new works executed by him during the past year had cost about half a million, besides those in progress at Sheerness, which would cost a million. He was then busy with his investigations relative to New London Bridge, the report on which he prepared while laid up with an attack of gout. He persisted in going abroad as long as he could, and went to his doctor in a carriage for advice, instead of letting the doctor come to him. But his resistance, however brave, was useless against disease, and at length he was compelled to succumb.

To the last, he went on issuing instructions to his inspectors in different parts of the country relative to the works then in progress,—the docks at Chatham and Sheerness, the harbours at Howth and Kingstown, the bridge at New Galloway, the Eau Brink Cut, the Aire and Calder Navigation, and the pumping-engines for Bottesham and Swaffham, in the Fens. He was especially anxious about the Eau Brink Cut, nearly ready for opening, urging his assistants to report to him from time to time, giving full particulars of the progress made. In the midst of all this, he writes a letter to a harbour-master at Bridlington, giving him detailed instructions as to the arrangement of tide tables! His last business letter was written to the Navy Board respecting the proper kind of gates to be used for the dry dock at Pembroke: it was dated the 28th September, 1821. A little before this he had written to his friend Mr. Jerdan, the Edinburgh engineer, that he had completed all business connected with his preparation for the next session of Parliament, when he had many bills to carry through.

But how often are the intentions of the bravest defeated! Day by day he grew weaker, struggling with the whole force of his will against the disease that was slowly mastering him. Although extremely ill, he insisted on rising from his bed, and tottered about, even taking an occasional airing in a carriage. In this state he continued until the 4th of October. On that day he did not get up. His mind had until then been as clear and vigorous as ever; but now it began to wander. There was no resisting the hand of death, which was already upon him. He took no further heed of what passed around him, and about five in the evening, he was seized by a fit of paralysis, from which he never rallied. About an hour later he expired, in the sixty-first year of his age.

The portrait prefixed to this memoir expresses, so far as an accurate delineation of his features can do, the actual character of the man. It is grave and thoughtful, yet has an expression of mildness perfectly in unison with his gentle yet cheerful disposition. Raeburn painted his portrait, and Chantrey chiselled his bust; but the chalk drawing by Archibald Skirving,* after which our engraving, is made, is on the whole the most lifelike representation of the man as he lived. In person he was large, tall, and commanding; and strength was one of the attributes belonging to his family.

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* Archibald Skirving, like John Rennie, was the son of an East Lothian farmer. He was born in 1749, at Garleton, a farm belonging

But physical endurance has its limits, and we fear that Mr. Rennie taxed his powers beyond what they would fairly bear. He may be said to have died in harness, in the height of his fame, after threescore years, forty of

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to the Earl of Wemyss. His father, Adam Skirving, was a well-known humorist and ballad-maker—one of his songs, 'Hey, Johnny Cope,' a description of the rout of the royal army at the battle of Prestonpans, being still popular in Scotland. In early life Archibald went to Rome to study art, and remained in Italy nine years. He walked back the whole way from Rome, but, passing through France, the revolutionary war broke out, when he was apprehended and thrown into prison, where he lay for nine months. He subsequently studied painting under David. Returned to Scotland, he pursued his art in a somewhat desultory manner, not being under the necessity of applying himself to it with that patient and continuous devotion which is essential to attaining high eminence in any profession. He painted when, where, and whom he pleased; and sometimes pursued a very singular course with his sitters. Notwithstanding his eccentricity, Skirving was an extremely clever artist, and his crayon drawings have rarely been surpassed for vigour and brilliancy. He executed probably the best head of Burns the poet, with whom he was intimate; and the portrait of John Rennie, which Mr. Holl has rendered with great skill, will give a good idea of Skirving's power as a delineator of character. Skirving and Rennie were intimate friends, although in most respects so unlike each other. Yet Skirving had as true a genius; and might have secured as great a reputation in his own walk as his friend Rennie, had he worked as patiently and industriously. As he grew older, he became more eccentric and sarcastic. He dressed oddly, in a broad-brimmed white hat, without any neckcloth. Allan Cunningham relates the story of Skirving's calling on Chantrey while he was finishing the bust of Bird, the artist. "Well! — and who is that?" asked Skirving. "Bird, the eminent painter." "Painter!—and what does he paint?" "Ludicrous subjects, Sir." "Ludicrous subjects! — Have *you* sat?" "Yes—he has had one sitting; but when he heard that a gentleman with a white hat, who wore no neckcloth, had arrived from the North, he said, 'Go—go; I know of a subject more ludicrous still: Skirving is come!'" This odd, but clever artist died at Inveresk, near Edinburgh, in 1819, at the advanced age of seventy which had been spent in hard work; still his death was premature, and in the case of a man of such useful gifts, it was much to be lamented. He himself held that life was made for work; and he could never bear to be idle. Work was with him not only a pleasure, it was almost a passion. He sometimes made business appointments at as early an hour as five in the morning, and would continue incessantly occupied until late at night. It is clear that the most vigorous constitution could not long have borne up under such a tear and wear of vital energy as this.

He was very orderly, punctual, and systematic, and was hence enabled to get through such an enormous amount of business. No matter how numerous were the claims upon his time, nothing was neglected nor hurried. His reports were models of what such documents should be. They set forth all the facts bearing upon the topic under consideration, in great detail; but with much plainness, force, and clearness. His harbour reports were especially masterly; in them he elaborately stated all the known facts as to the prevailing winds, currents, and tides, usually drawing very logical and conclusive inferences as to the particular plan which, under the circumstances, he considered it the most desirable to adopt. In his estimates he was careful to conceal nothing, stating the full sum which in his judgment the work under consideration would cost; nor would he understate the amount by one farthing in order to tempt projectors to begin any undertaking on which he was consulted.

He took the highest ground in his dealings with contractors. He held that the engineer was precluded by his position from mixing himself up with their business, and that if he dabbled in shares or contracts, either openly or underhand, half his moral influence was gone, and his character liable to be seriously compromised. Writing to Playfair at Edinburgh, in 1816, he said—"Engineers should be entirely independent of these connections—not dabblers in shares—and free alike of contractors and contracts." By holding scrupulously to this course, Mr. Rennie established a reputation for truthfulness, honesty, and uprightness, not less honourable and exalted than his genius as an architect and an engineer was illustrious.

He was a man of powerful and equally balanced mind—not so clever, as profound; not brilliant, but calm, serene, and solid, like one of his own structures. While he lay on his deathbed, his last letters to his assistants urged upon them attention, punctuality, and despatch—qualities which he himself had illustrated so well in his own life. In his self-education he had overlooked no branch of science cultivated in his day; and in those which bore more especially upon his own calling, his knowledge was well-arranged, complete, and accurate.

Withal he was an exceedingly modest, unpretending, and retiring man. His great aim was to do the thing he was appointed to do in the best possible manner. He thought little of fame, but a great deal of character and duty. If his time was so entirely pre-occupied that he could not personally devote the requisite attention to any new undertaking brought before him, he would decline to enter upon it, and recommended the employment of some other leading engineer. He considered it his duty himself to go into the minutest details of every business on which he was consulted. He left as little as possible to subordinates, making his calculations and estimates himself; and he wrote and even copied his own reports, perhaps improving them in the copying; deeming no point, however apparently unimportant, beneath his careful attention and study.

Hence great reliance was placed upon his judgment by those who consulted him; and the accurate though comparatively reserved manner in which he expressed himself before Committees of Parliament, gave all the greater weight to his evidence. "What I liked about Rennie," says one who knew him well, "was his severe truthfulness." When under examination on such occasions, he could always give a strong clear reason, in support of any scheme he recommended, based upon his own careful preliminary study of the whole subject. But when asked any question outside the line of his actual knowledge, he had the honesty to say at once, "I do not know." He would not guess nor attempt to give ingenious answers to show his cleverness, nor act the special pleader in the witness-box, but confine himself solely to what he positively knew.

In the course of his professional career, Mr. Rennie experienced the great advantage which he had derived from his early training as a millwright. His practical knowledge enabled him to select the best men to carry out his designs, and he took pride and pleasure in directing them how to do their work in the most efficient manner. His manufactory was indeed a school, in which some of the best mechanics of the day received a thorough training in machine work; and many of his workmen, like himself, eventually raised themselves to the rank of large employers of skilled labour. Mr. Rennie was never ashamed to put his hand to any work where he could teach a lesson or facilitate despatch, and to the end of his career he continued as "handy" as he had been at the beginning.

A curious illustration of his expertness at smith-work occurred during a journey into Scotland, when on his way to visit the Earl of Eglinton at Eglinton Castle. He went by the stage-coach, in company with some Ayrshire farmers and one or two rather important "Paisley bodies." When travelling over a very bad piece of the road, the jolting was such as to break the axletree of the coach, and it came to a stand on a solitary moor, with not a house in sight. Mr. Rennie asked the coachman if there was any blacksmith near at hand, and he was told there was one a mile or two off. "Well, then, help me to carry the parts of the axle there, and I'll see to its being mended." The blacksmith, however, was not at home; but Mr. Rennie forthwith lit the forge fire, blew the bellows, and with the rather clumsy assistance of one of his fellow-passengers, he very soon welded the axle in a workmanlike manner, helped to carry it back to the coach, and after the lapse of a few hours the vehicle was again wheeling along the road towards its journey's end.

Mr. Rennie's fellow-passengers, who had been communicative and friendly during the earlier part of the journey, now became very reserved, and the "boddies" especially held themselves aloof from "the blacksmith," who had so clearly revealed his calling by the manner in which he had mended the broken axle. Arrived at their journey's end for the day, the travellers separated; Mr. Rennie proceeding onwards to Eglinton Castle. Next morning, when sitting at breakfast with his noble host, a servant entered to say that a person outside desired to have a word with the Earl. "Show him in." The person entered. He proved to be one of Mr. Rennie's fellow-travellers; and great indeed was his surprise and confusion at finding the identical blacksmith of the preceding day, breakfasting with "my Lord"! The Earl was much amused when Mr. Rennie afterwards described to him the incident of the mending of the broken axle.

One of his few hobbies was for old books; and if he could secure a few minutes' leisure at any time, he would wander amongst the old book-stalls in search of rare volumes. Froissart's and Monstrelet's 'Chronicles' were amongst his favourites, and we find him on one occasion sending a present of duplicate copies to his friend Whidbey, accompanied with the wish that he might derive as much pleasure from their perusal as he himself always did from reading "honest John Froissart." He also commissioned his friends, when travelling abroad, to pick up old books for him; and in 1820 we find him indulging his "extravagance," as he termed it, so far as to request Sir William Jolliffe to bring 300*l.* worth of old books for him from Paris.

Although Mr. Rennie realized a competency by the practice of his profession, he did not accumulate a large fortune. The engineer was then satisfied with a comparatively moderate rate of pay, very different from the slashing charges of modern railway engineers.

We do not wonder that Mr. Rennie complained of the small remuneration of 350*l.* awarded to him by the Kennet and Avon Canal Company for constructing their canal works; and we are surprised to find his bill against the Manchester Waterworks Company for his year and-a-half's advice and service, amounting to only 159*l.* 7*s.*, his charge to them for a whole day's labour being only six guineas.

Mr. Rennie's charge of seven guineas for an entire day's work, was afterwards objected to by General Brownrigg, the head of the Ordnance Department. "Why, this will never do," said the General, looking over the bill; "seven guineas a-day! Why, it is equal to the pay of a Field Marshal!" "Well," replied Mr. Rennie, "I am a Field Marshal in my profession; and if a Field Marshal in your line had answered your purpose, I suppose you would not have sent for me!" "Then you refuse to make any abatement?" "Not a penny," replied the engineer; and the bill was paid.

Mr. Rennie was blamed in his time for the costliness of his designs, and it was even alleged of him that he carried his love of durability to a fault. But there is no doubt that the solidity of his structures proved the best economy in the long run. Elevated by his genius and his conscientiousness above the thoughts of immediate personal gain, no consideration would induce him to recommend or countenance in any way the construction of cheap or "shoddy" work.

He held that the engineer had not merely to consider the present but the future, in laying down and carrying out his plans. Hence his designs of docks and harbours were usually framed so as to be capable of future extension; and his bridges were built not only for his own time, but with a view to the uses of generations to come.

In fine, Mr. Rennie was a great and massive, yet a perfectly simple and modest man; and though his engineering achievements may in some measure have been forgotten in the eulogies bestowed upon more recent works, they have not yet been eclipsed, nor indeed equalled; and his London bridges—not to mention his Docks, Harbours, Breakwaters, and Drainage of the Fens—will long serve as the best exponents of his genius.

The death of this eminently useful man was felt to be a national loss, and his obsequies were honoured by a public funeral. His remains were laid near those of Sir Christopher Wren in St. Paul's Cathedral, the dome of which overlooks some of his greatest works.

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